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Manitoba
Agriculture

29th ANNUAL REPORT

MANITOBA SOCIETY OF SOIL SCIENCE MEETING

**Papers Presented at the
29th Annual Meeting
Held January 7th and 8th,
1986**

86-04284/

PAPERS PRESENTED

AT THE

29th Annual

MANITOBA SOCIETY

SOIL SCIENCE MEETING

HOLIDAY INN SOUTH
WINNIPEG

JANUARY 7 and 8, 1986

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PROGRESS REPORT OF 1985-86 SOIL SURVEY PROJECTS IN MANITOBA

R.E. Smith
Canada-Manitoba Soil Survey

Highlights of the joint federal-provincial Canada-Manitoba Soil Survey Project for the review period April 1, 1985 to March 31, 1986 include inventory in Manitoba, continued development of improved soil survey procedures, and publication of a significant number of soil survey reports and technical papers.

INVENTORY - MANITOBA

a) 1985 Detailed Resurveys, Correlation and Other Field Investigations

A total of approximately 288 sq. miles at 1:20K and 187 sq. miles at 1:50K for a total of 475 sq. miles were resurveyed in selected areas of the South-central and western section of the Red River Valley regions of the province. Detailed initial survey of 6 sq. miles of the rugged, rocky terrain surrounding the northern mining community of Snow Lake, for infrastructure planning, was also completed.

Field correlation and soil map enhancement of the published Swan River project (R10) with the unpublished Swan Lake project (R18) is approximately 50 percent complete. Project R18 has been revised and will include R10 map and other data for this area as well as for Porcupine Forest Reserve, the resurveys of the area surrounding the townsite of Swan River, D37; a portion of the R.M. of Swan River, D66; the Red Deer Lake area survey, R25; and an east-west strip of land 2 twps. high extending from Sclater east to Camperville that lies between R18 to the north and Grandview, R7 to the south.

Other soil investigations included initiating a 125K scale survey of the Duck Mountain Forest Reserve, completing soil characterization studies of 5 forestry regeneration plots being affected by Inco Smelter Stack heavy metal and other air pollutant fallout near Thompson, verification of the water erosion and salinity risk assessment 1:1M scale maps.

Table 1. Detailed Resurvey Coverage 1985

Project		Coverage in Sq. Miles	
		1:20K	1:50K
Manitoba Agriculture and Federal Agriculture			
R29	R.M. Lorne	15	45
R32	Whitemouth Peatland		80
D60	Twps. 4-9, Rge. 3W in the R.M.'s of Grey, Dufferin, Roland	216	
R34	R.M. South Norfolk*	9	32
Municipal Affairs - Planning			
D4-D35	LDG Park	15	
D65	Newdale, Birtle, Shoal L.	9	
D68	R.M. MacDonald (SW City of Wpg. Perimeter, Sanford-La Salle, Brunkild)	18	
D69	Snow Lake Townsite*	6	

Table 1 (continued)

Project	Coverage in Sq. Miles 1:20K	1:50K
Municipal Affairs - Land Assessment		
R31 R.M. Woodlands		30
R33 Rockwood 1:125K Soil Map upgrade and standardization		
Total Area Covered (Sq. miles)	288	187=475

* Survey continuing in 1986

b) Soil Map and Report Production 1985-86

R17 Waterhen (Rpt. No. 23) 949,600 ha, 1:125K, colored maps and report available Publications Br., Provincial Queen's Printer.

R20 Grand Rapids 675,031 ha 1:125K, colored maps only available from Soil Survey, Univ. of Manitoba.

D51 Westbourne R.M., 51,456 ha, 1:20K, B & W air photo map base available Publications Br., Provincial Queen's Printer.

D53 Altona, Gretna, Emerson, Ile de Chene, Landmark, Lettelier, Rosenort and St. Jean Baptiste, 14,080 ha, 1:20K, B & W air photo base maps & report available Publications Br., Porovincial Queen's Printer.

D55 St. Rose du Lac, 3,584 ha, 1:20K, B & W air photo base map and report available Publications Br., Provincial Queen's Printer.

D56 Souris, Wawanesa, Virden, 6,400 ha, B & W air photo base maps and report available Publications Br., Provincial Queen's Printer.

D58 Hallboro-Minnedosa, 4,544 ha, B & W air photo base maps and report available Publications Br., Provincial Queen's Printer.

D59 Beaudry Park, 640 ha, B & W air photo base map and report available Soil Survey, Univ. of Man.

- Mapping of Soils & Bedrock Sensitivity to Acidic Deposition in Manitoba, 54.8 million ha, 1:2M scale, 2 colored maps and a report, Wotton, D.L. & Haluschak, P., available Soil Survey, University of Manitoba or Dept. of Environment, Work Place Safety & Health, Rpt. 86-1.

R9 Fisher-Teulon (Report No. 9), 949,200 ha, 1:100K, 2 colored maps and a report, reprinted 1986, available Publications Br., Provincial Queen's Printer.

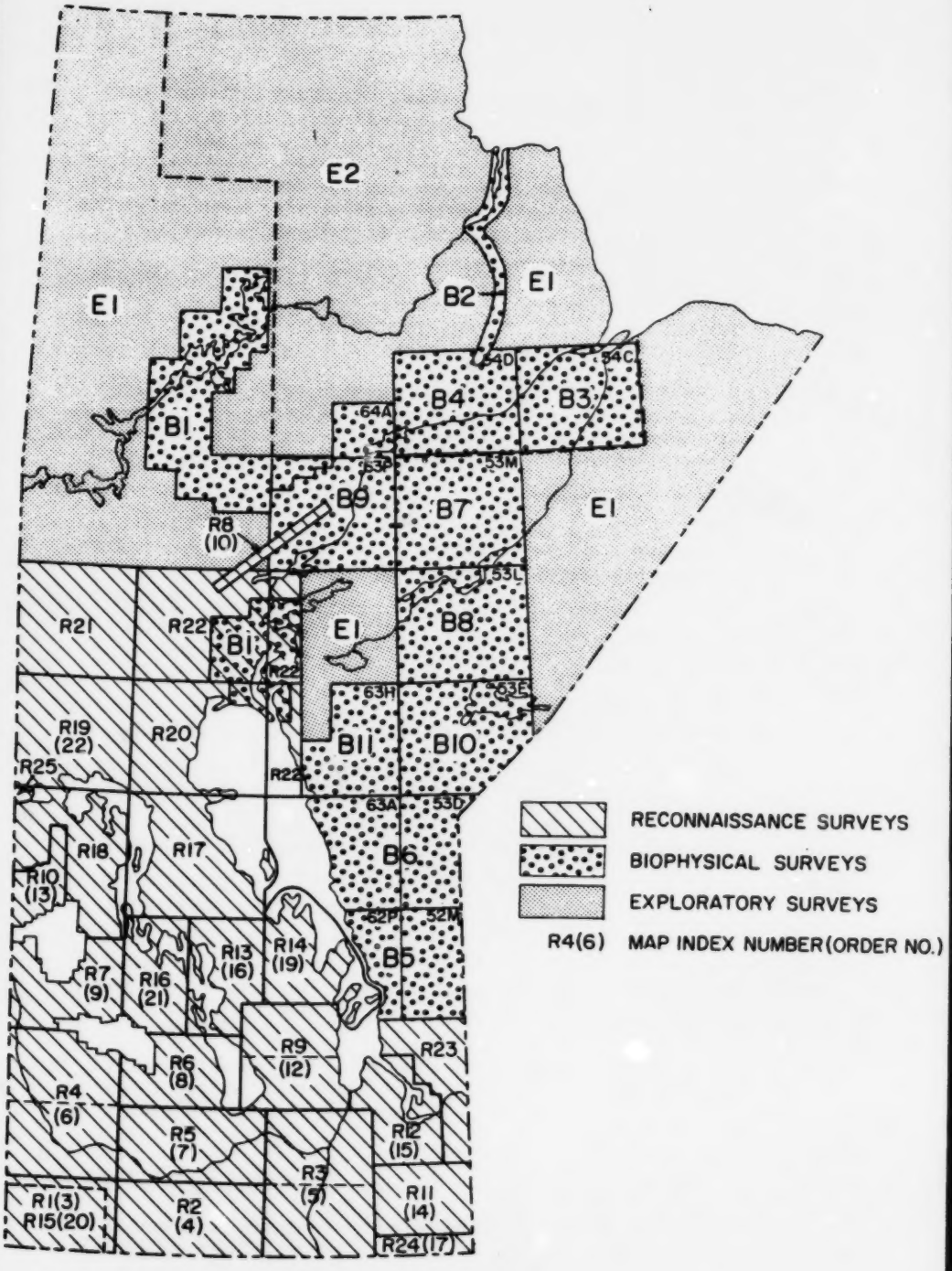
c) Soil Survey Procedures R and D

Incremental progress has been made in improving irrigation suitability classification guidelines, soil water regime classification, soil salinity classification criteria and improved soil temperature data evaluation and collection methods through the work of the Expert Committee on Soil Survey (ECSS) working groups and other interested

prairie region groups presently being coordinated through the Winnipeg Pedology Unit, LRRI.

Development of the national Soil Survey Handbook continues with contributions to Chapter 500 (applications of survey information to various uses) and to Chapter 600 (soil investigations methods).

Progress has also been made in improving the Manitoba-CanSIS node through acquisition of stand-alone soil map digitizing hardware and in developing the use of hand-held electronic micro computers or data loggers to capture field data.



LOCATION OF RECONNAISSANCE AND BIOPHYSICAL SURVEYS

SUMMARY OF SOIL SURVEY COVERAGE FOR MANITOBA
JANUARY, 1986

Map Project Designation	Name (Soil Report No.)	Report[1] Status	Area in Hectares	Map Unit[2] Description	Survey[3] Intensity Level	Map Scale	Map[4] Base	Land Evaluation[5] & Interpretations
Detailed Studies and Surveys								
D1	Pasquia (No. 11)	Pub. 1960	57 200	a,b,d	3	1:63,360	Color	A
D2	Glenlea Research Station	Int. 1963	541	a,b	1	1:7,920	Photo	A
D3	Morden Experimental Farm	Int. 1961	256	a,b	1	1:12,000	Photo	A
D4	Onanole	Int. 1968	768	a,b	1	1:7,920	Photo	U
D5	York Factory Area	Int. 1969	768	a	3	1:63,360	B&W	
D6	McCreary Tile Drain Project	Int. 1971	64	a,b	1	1:5,000	B&W	A
D7	Brandon Experimental Farm	Int. 1985	768	a,b	1	1:7,920	Photo	A
D8	Portage Potato Farm	Int. 1972	480	a,b	1	1:4,800	Photo	A
D9	Portage la Prairie (No. 17)	Pub. 1972	113 200	a,b,c	2	1:20,000	Photo	A,I,E,U,R
D10	Morden-Winkler (No. 18)	Pub. 1973	71 424	a,b,c	2	1:20,000	Photo	A,I,E,U,R
D11	Deep Lake	Int. 1975	1 400	a,b	1	1:6,000	B&W	R
D12	Thompson Environmental Study	Int. 1976	32	a,b	1	1:1,000	B&W	
D13	Organic Soil Study of Alexander L.G.D.	Int. 1975	29 456	a,b	3	1:63,360	B&W	A
D14	Winnipeg Region	Pub. 1975	280 000	a,b,c	2	1:20,000	Photo	A,E,U,R
D15	Brandon Region	Pub. 1976	59 600	a,b,c	2	1:20,000	Photo	A,E,U,R
D16	Boissevain-Melita (No. 20)	Pub. 1978	262 912	a,b,c	2	1:20,000	Photo	A,I,E,U,R
D17	Carman	Pre.	73 905	a,b	2	1:20,000	B&W	A,E,R
D18	Orr Lake	Int. 1977	20	a,b	1	1:1,000	B&W	
D19	Pelican-Rock Lake	Int. 1983	14 080	a,b	2	1:20,000	Photo	A,E,R,I
D20	West Portage	Int. 1982	120 956	a,b	2	1:20,000	Photo	A,I,E,R
D21	Minnewasta	Int. 1978	2 560	a,b	2	1:20,000	Photo	A,E,R,I
D22	Killarney	Int. 1979	4 600	a,b	2	1:20,000	Photo	A,E,R,I
D23	Matlock-Gimli-Riverton	Int. 1981	18 400	a,b	2	1:20,000	Photo	A,E,R,I
D24	Glenboro	Int. 1979	5 960	a,b	2	1:20,000	Photo	A,E,R,I
D25	Sandy Lake	Int. 1980	1 720	a,b	2	1:20,000	Photo	A,E,R,I
D26	Brokenhead	Int. 1979	10 813	a,b	2	1:20,000	Photo	A,E,R,I,U
D27	Rockwood	Int. 1980	12 928	a,b	2	1:20,000	Photo	A,E,R,I,U
D28	Oak Lake	Int. 1979	1 293	a,b	2	1:20,000	Photo	A,I
D29	Bird River	Int. 1980	2 560	a,b	2	1:20,000	Photo	A,E,R
D30	North Shore Lac du Bonnet	Int. 1980	2 400	a,b	2	1:20,000	Photo	A,E,R
D31	Grindstone Point	Int. 1979	8 040	a,b	2	1:20,000	Photo	A,E,R

SUMMARY OF SOIL SURVEY COVERAGE FOR MANITOBA (continued)
JANUARY, 1986

Map Project Designation	Name (Soil Report No.)	Report[1] Status	Area in Hectares	Map Unit[2] Description	Survey[3] Intensity Level	Map Scale	Map[4] Base	Land Evaluation[5] & Interpretations
D32	Paint Lake	Int. 1980	2 880	a,b	2	1:10,000	Photo	A,E,R
D33	Cranberry Portage	Int. 1980	80	a,b	1	1:5,000	Photo	A,E,R
D34	Dauphin	Int. 1981	6 400	a,b	2	1:20,000	Photo	A,E,R,I
D35	South Riding Mtn.	Pre.	23 488	a,b	2	1:20,000	Photo	A,E,R
D36	West Interlake	Int. 1981	10 036	a,b	2	1:20,000	Photo	A,E,I,R
D37	Swan R. Townsite	Pre.	7 680	a,b	2	1:20,000	Photo	A,E,R,I
D38	Hadashville-organic	Int. 1981	6 475	a,b	3	1:40,000	Photo	A,E,I,R
D39	Part of L.G.D. Stuartburn (Rat River)	Pre.	27 972	a,b	3	1:40,000	Photo	A,E,I,R
D40	Falcon L-Brereton L	Pre.	25 900	a,b	2	1:20,000	Photo	A,E,R
D41	Quesnel Lake-North Shore Winnipeg River	Pre.	3 000	a,b	2	1:20,000	Photo	A,E,R
D42	Duck Mountain	Int. 1982	3 036	a,b	2	1:20,000	Photo	A,E,R
D43	Spruce Woods	Pre.	26 300	e	3	1:40,000	Photo	A,E,R
D44	McGregor	Int. 1982	3 910	a,b	2	1:20,000	Photo	A,E,R
D45	Pine Creek	Int. 1983	1 942	a,b	2	1:20,000	Photo	A,E,R,I
D46	Arborg-Riverton	Int. 1982	2 590	a,b	2	1:20,000	Photo	A,E,R,I
D47	Roblin	Int. 1983	4 096	a,b	2	1:20,000	Photo	A,E,R,I
D48	Flin Flon	Pre.	4 600	a,b	2	1:20,000	Photo	A,E,R
D49	St. Anne-La Broquerie	Pre.	74 592	a,b	3	1:40,000	Photo	A,E,R,I
			4 662	a,b	2	1:20,000	Photo	A,E,R,I
D50	City of Brandon	Int. 1984	2 980	a,b	2	1:20,000	Photo	A,E,R,I
D51	Westbourne	Int. 1985	51,456	a,b	2	1:20,000	Photo	A,E,R,I
D52	Notre Dame, Rathwell, Treherne Townsites	Int. 1984	6 144	a,b	2	1:20,000	Photo	A,E,R,I
D53	Altona, Emerson, Gretna, Ile des Chenes, Landmark, Letellier, Rosenort, St. Jean Townsites	Int. 1984	14 080	a,b	2	1:20,000	Photo	A,E,R,I
D54	Russell, Binscarth-Townsites	Int. 1984	3 584	a,b	2	1:20,000	Photo	A,E,R,I
D55	St. Rose Du Lac-Townsite	Int. 1985	1 536	a,b	2	1:20,000	Photo	A,E,R,I
D56	Souris, Wawanesa, Virden, Townsites	Int. 1986	6 400	a,b	2	1:20,000	Photo	A,E,R,I
D57	Fraserwood, Inwood, Komarno Townsites, Lake Man. Shoreline	Pre.	1 856	a,b	2	1:20,000	Photo	A,E,R,I
D58	Hallboro, Minnedosa-Townsites	Int. 1984	4 544	a,b	2	1:20,000	Photo	A,E,R,I
D59	Beaudry Park	Data	640	a,b	2	1:20,000	Photo	A,E,R
D60	Portions of Dufferin, Grey, and Roland	Data	68 488	a,b	2	1:20,000	Photo	A,E,R,I
D61	Meditation Lake	Data	3 072	a,b	2	1:20,000	Photo	A,E,R
D62	Wanipigow Lake	Data	8 960	a,b	2	1:20,000	Photo	A,E,R

SUMMARY OF SOIL SURVEY COVERAGE FOR MANITOBA (continued)
JANUARY, 1986

Map Project Designation	Name (Soil Report No.)	Report[1] Status		Area in Hectares	Map Unit[2] Description	Survey[3] Intensity Level	Map Scale	Map[4] Base	Land Evaluation[5] & Interpretations
D63	Shellmouth Resevoir-N	Data		4 650	a,b	2	1:20,000	Photo	A,E,R,I
D64	Assiniboine River	Pre.		4 095	a,b	2	1:20,000	Photo	A,E,R,I
D65	Villages of Hamiota, Strathclair, Rapid City, Newdale, Birtle, Shoal Lake	Pre.		5 180	a,b	2	1:20,000	Photo	A,E,R,I
D66	Springfield R.M.	Pre.		13 440	a,b	2	1:20,000	Photo	A,E,R,I
D67	St. Eustache, Springstein, Perimeter Strip, Brunkild, La Salle R.	Pre.		6 200	a,b	2	1:20,000	Photo	A,E,R,I
D68	Spruce Point Mine Area	Pub.		450	a,b	2	1:10,000	Photo	E,R
D69	Snow Lake	Data							
Reconnaissance Surveys									
R1	South Western (No. 3)	Pub.	1940	709 600	d	3	1:125,000	B&W	A
R2	South Central (No. 4)	Pub.	1943	967 600	d	3	1:125,000	B&W	A
R3	Winnipeg and Morris (No. 5)	Pub.	1953	1 419 200	d	3	1:125,000	Color	A
R4	Rossburn and Virden (No. 6)	Pub.	1956	1 372 400	d	3	1:125,000	Color	A
R5	Carberry (No. 7)	Pub.	1957	967 600	d	3	1:125,000	Color	A
R6	West-Lake (No. 8)	Pub.	1958	592 800	d	3	1:125,000	Color	A
R7	Grandview (No. 9)	Pub.	1957	689 200	d	3	1:125,000	Color	A
R8	Nelson River Basin (No. 10)	Pub.	1973	224 000	b	3	1:100,000	Color	A
R9	Fisher and Teulon (No. 12)	Pub.	1961	949 200	a,c	3	1:100,000	Color	A
R10	Swan River (No. 13)	Pub.	1962	316 000	a,c	3	1:125,000	Color	A
R11	South Eastern (No. 14)	Pub.	1964	749 200	a,c	3	1:125,000	Color	A,F
R12	Lac du Bonnet (No. 15)	Pub.	1967	764 800	a,c	3	1:125,000	Color	A,F,R
R13	Grahamdale (No. 16)	Pub.	1971	764 800	a,b	3	1:125,000	Color	A,F,U,R,E
R14	Red Rose-Washow Bay (No. 19)	Pub.	1975	704 400	a,b	3	1:125,000	Color	A,F
R15	Boissevain-Melita (No. 20)	Pub.	1978	299 520	a,b	2	1:40,000	Photo	A,I,E
R16	Ste. Rose (No. 21)	Pub.	1981	676 705	a,b	3	1:125,000	Color	A,I,R,E,F
R17	Waterhen (No. 23)	Pub.	1985	949 600	a,b	4	1:125,000	B&W	A,I,R,E,F
R18	Swan Lake	Data		599 200	a,b	3,4	1:125,000	B&W	A
R19	The Pas (No. 22)	Pub.	1982	791 700	a,b	4	1:125,000	Color	A,I,E,R,F
R20	Grand Rapids	Pre.		675 031	a,b	4	1:125,000	B&W	A
R21	Cormorant	Int.	1975	920 000	a,b	4	1:125,000	B&W	A
R22	Wekusko	Pre.		1 400 000	a,b	4	1:125,000	B&W	A
R23	Pointe du Bois	Data		740 000	a,b				
R24	Roseau River	Pub.	1977	45 200	a,b	3	1:63,360	B&W	A
R25	Red Deer Lake	Pub.	1966	34 860	a,b	2	1:31,680	Photo	A
R26	Cross Lake and Norway House	Pre.		615 200	a,b	4	1:125,000	B&W	A
R27	South Central - Escarpment	Pre.		107 744	a,b	2,3	1:40,000	Photo	A,E,R
R28	Pasquia Lake	Pub.	1984	2 330	a,b	3	1:50,000	B&W	A,E
R29	Lorne R.M.	Pre.		512	a,b	2	1:20,000	Photo	A,E,R,I
				4 608	a,b	2	1:20,000	Photo	A,E,R,I
				73 728	a,b	3	1:50,000	N.T.S.	A,E,R,I

SUMMARY OF SOIL SURVEY COVERAGE FOR MANITOBA (continued)
JANUARY, 1986

Map Project Designation	Name (Soil Report No.)	Report[1] Status	Area in Hectares	Map Unit[2] Description	Survey[3] Intensity Level	Map Scale	Map[4] Base	Land Evaluation[5] & Interpretations
R30	Benito	Pre.	18 432	a,b	3	1:50,000	Photo	A,E,R,I
R31	R.M. Woodlands	Pre.	9 980	a,b	3	1:50,000	Photo	A,E,R,I
R32	Whitemouth Peatland		10 240	a,b	3	1:50,000 1:125,000		
R33	R.M. Rockwood							
R34	R.M. South Norfolk	Pre.	7 936	a,b	3	1:50,000	N.T.S.	A,E,R,I
			2 304	a,b	2	1:20,000	Photo	A,E,R,I

SUMMARY OF SOIL SURVEY COVERAGE FOR MANITOBA (continued)
JANUARY, 1986

Map Project Designation	Name (Soil Report No.)	Report[1] Status	Area in Hectares	Map Unit[2] Description	Survey[3] Intensity Level	Map Scale	Map[4] Base	Land Evaluation[5] & Interpretations
Biophysical and Exploratory Surveys								
B1	Lake Winnipeg, Churchill & Nelson Rivers	Pub. 1973	3 600 000	e	4	1:250,000 1:50,000	B&W	
B2	Churchill Transportation Corridor	Data 1974	179 000	f	4	1:125,000	B&W	
B3	54C Hayes River	Int. 1976	1 370 300	f	4	1:125,000	B&W	
B4	54D Kettle Rapids	Int. 1976	1 370 300	f	4	1:125,000	B&W	
B5	52M Carrol Lake	Int. 1977	634 000	f	4	1:125,000	B&W	
B5	62P Hecla	Int. 1977	466 200	f	4	1:125,000	B&W	
B6	53D Deer Lake	Int. 1978	629 700	f	4	1:125,000	B&W	
B6	63A Berens River	Int. 1978	848 500	f	4	1:125,000	B&W	
B7	53M Knee Lake	Int. 1978	1 405 900	f	4	1:125,000	B&W	
B8	53L Oxford House	Int. 1978	1 441 100	f	4	1:125,000	B&W	
B8	63H Norway House	Data	540 800	f	4	1:125,000	B&W	
B9	SE 1/4 64A Split Lake	Int. 1979	342 400	f	4	1:125,000	B&W	
B9	63P Sipiwesk	Int. 1979	1 405 900	f	4	1:125,000	B&W	
B10	53E Island Lake	Pre.	1 286 900	f	4	1:125,000	MSS	
B11	63H Norway House	Data				1:125,000	B&W	
E1	Surface Deposits & Soils of Northern Manitoba	Int. 1963		g	5	1:1,267,000	B&W	
E2	Exploratory Terrain Study of Northern Manitoba and Southern Keewatin, N.W.T.	Int. 1974		g	5	1:1,000,000	B&W	

1. Report Status
   Pub.-Published Report and Map
   Int.-Interim Report and Map Available
   Pre.-Preliminary Map and Legend Available
   Data-Field Data Available Only

2. Map Unit Descriptions Code
   a-single series and phases
   b-series complexes defined as to proportion
   c-series complexes undefined as to proportion
   d-associations
   e-biophysical units (materials and physiography)
   f-biophysical units (associations & complexes of associations)
   g-regional and local physiographic units

3.Survey Intensity Levels

Code	Name	Scale	Minimum Size Delineation(ha)	Inspection Density (Approx. range)
1	Very detailed	>1:12,000	<1.5	>1 per 3 ha
2	Detailed	1:12,000 to 1:40,000	1.5-16	1 per 3 to 50 ha
3	Semi-detailed	1:40,000 to 1:125,000	16 to 256	1 per 10 to 1 000 ha
4	Reconnaissance	1:125,000 to 1:250,000	256 to 625	1 per 100 to 110 000 ha
5	Exploratory	1:250,000 to 1:1,000,000	625 to 110 000	1 per 300 to 500 000 ha

4.Published Map Base Code

Photo-Photomosaic
B&W -Black and white line
Color-Colored line

5.Interpretations Code

A-Agriculture Capability
E-Engineering
F-Forestry
I-Irrigation Suitability
U-Urban Planning and Community Development
R-Recreation

TOTAL HECTARAGE COVERED

	1985	To Date
Initial Reconnaissance	---	18,619,436
Initial Detailed survey	1,554	18,014
Detailed Resurvey	123,029	1,970,192
Biophysical Survey	---	12,521,000

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THE NATURE AND EXTENT OF SEASONALLY AND PERMANENTLY FROZEN SOILS (CRYOSOLS) IN MANITOBA

R.E. Smith, G.F. Mills, H. Veldhuis and P. Haluschak
Canada-Manitoba Soil Survey

EXTENT AND DISTRIBUTION OF SEASONALLY AND PERMANENTLY FROZEN SOILS

The soils of Manitoba are profoundly affected by frost action processes. The province can be subdivided into four zones from the point of view of seasonal or permanent effects of such intense frost action processes as frost heaving and differential thrusting, frost cracking, ice drift grooving and on the extent and distribution of the products of these processes (see Figure 1, Table 1).

Approximately 15.6 million ha or 28 percent of the 54.8 million ha of Manitoba's total land surface is comprised of Organic Cryosols, Turbic Cryosols and Static Cryosols. Of these soils Organic Cryosols comprise 11.9 million ha (76 percent), Turbic Cryosols 2.8 million ha (17.9 percent) and Static Cryosols 0.9 million ha (5.9 percent) (see Table 2).

CLIMATIC AND TOPOGRAPHIC PARAMETERS

The overriding independent factors controlling the distribution and extent of permafrost and Cryosolic soils are regional climate and topography (see Figures 2, 3, 4 and Table 3).

Climate

Mean annual air temperature ranges from 2.2°C in southern-most Zone 1 to lower than -7.2°C in Zone 4 (Table 3). Degree days above 0°C range from 2770 in the south to 1151 in the north, i.e. more than 60 percent less available heat. Thaw period precipitation in the north is approximately 50 percent less than that in the south. Twenty-five percent less of total annual precipitation falls in the form of rain during the thaw period in Zones 3 and 4 than in Zones 1 and 2. Both of these factors have had the effect of significantly reducing biomass production, biological activity and in preserving permafrost in Zones 3 and 4.

Relief and Drainage

If the 300 m contour is viewed as significant, more than two-thirds of the province is lowland. In the southwest the Interior Plains reaches its greatest elevation at about 600 m and is covered with a relatively thick, continuous blanket of hummocky, calcareous Wisconsin glacial till and is well drained. Northward, the Manitoba Lowland and the Canadian Shield, covering more than 70 percent of the province, consists of a nearly level to undulating bedrock dominated, poorly drained plain. It is this topographic control, in addition to a cold, humid climate, that has led to the development of vast expanses of organic soils (approximately 35 percent of total land area) in central and northern Manitoba.

DISTRIBUTION OF CRYOSOLIC SOILS IN MANITOBA

ZONE 1 Seasonally Frozen Soils

2 Southern Fringe of Discontinuous Permafrost

3 Widespread Discontinuous Permafrost

4 Nearly Continuous Permafrost

- Intersecting Icedrift Grooves
- Patterned Fens
- Fossil Ice Wedge Cast
- Varved Sediments

- > 85% Turbic and Static Cryosols
- > 70% Organic Cryosols
- 50-60% Organic Cryosols
  15-20% Turbic and Static Cryosols
- 35-40% Organic Cryosols
  15-20% Turbic and Static Cryosols
- 40-50% Organic Cryosols
  < 10% Static Cryosols
- 20-30% Organic Cryosols
- < 10% Organic Cryosols

Figure 1. Distribution of Cryosolic Soils in Manitoba

Table 1. Characteristics of Seasonally and Perennially Frozen Soil Landscapes in Manitoba

Zone, area, ha and % of Province	Occurrence of Permafrost; Depth to Frost Table; Structure of Ice; Degree of Cryoturbation	Area Affected by Permafrost ha (%)	Surface Expression: Contemporary (active)	Surface Expression: Relic (inactive)
1. Seasonally Frozen 17,857,000 (33%)	Mineral soils: Seasonally frozen to 1.5-2 meters; ice crystals visible in form of lenses and veins in saturated soils.	-	-	Fossil ice wedge casts; intersecting ice drift grooves; varved sediments.
	Organic soils: seasonally frozen, isolated outliers of permafrost in forest peat; .6-2 m; ice crystals in form of lenses and veins.	Trace (-)	Palsas and peat plateaus	Patterned fens, some collapse scars
2. Discontinuous, southern fringe permafrost 11,114,000 (20%)	Mineral soils: Seasonally frozen except for some poorly drained clayey soils; .60-1.00 m +; ice segregated into lenses and veins.	10,000	Minor occurrence of turfy hummocks	Subdued earth hummocks, varved sediments, cryoturbated in subsoil
	Organic soils: forest peat; .60-1.50 m; fen peat; seasonally frozen; ice segregated into lenses and veins.	1,366,300 (12%)	Peat plateaus & palsas with collapse scars; some veneer bogs	Patterned fens; collapse scars widespread
3. Discontinuous, widespread permafrost 17,910,200 (33%)	Mineral soils: Mid to lower slopes in sand (100 cm +); loam and clay (40-100 cm +); seasonally frozen or deep active layers >2.00 m in well drained sites of all materials; ice segregated into lenses and veins; profiles cryoturbated.	2,700,000	Earth hummocks; non-sorted circles widespread	Varved sediments, cryoturbated in subsoil; earth hummocks widespread; bouldery surfaces due to differential sorting of coarse fragments.
	Organic soils: forest peat and fen peat ridges; 40-60 cm; fen peat, non-frozen.	6,100,000 (48%)	Peat plateaus, palsas, veneer bogs	Patterned fens, collapse scars less prevalent in peat plateaus
4. Nearly Continuous permafrost 7,918,000 (14%)	Mineral soils: in all materials, 40-100 cm + except well drained sand in which active layer may exceed 2.0 m; profiles strongly cryoturbated.	1,100,000	Non-sorted circles, polygons, turfy hummocks, non-sorted stripes and steps	-
	Organic soils: forest peat and fen peat ridges; 40-60 cm; fen peat frozen with deep (>150 cm) active layer.	4,400,000 (70%)	Polygonal peat plateaus; peat plateaus, palsas, veneer bogs, minerotrophic palsas	-
TOTAL 54,800,000 (100%)		15,510,000 (28%)		

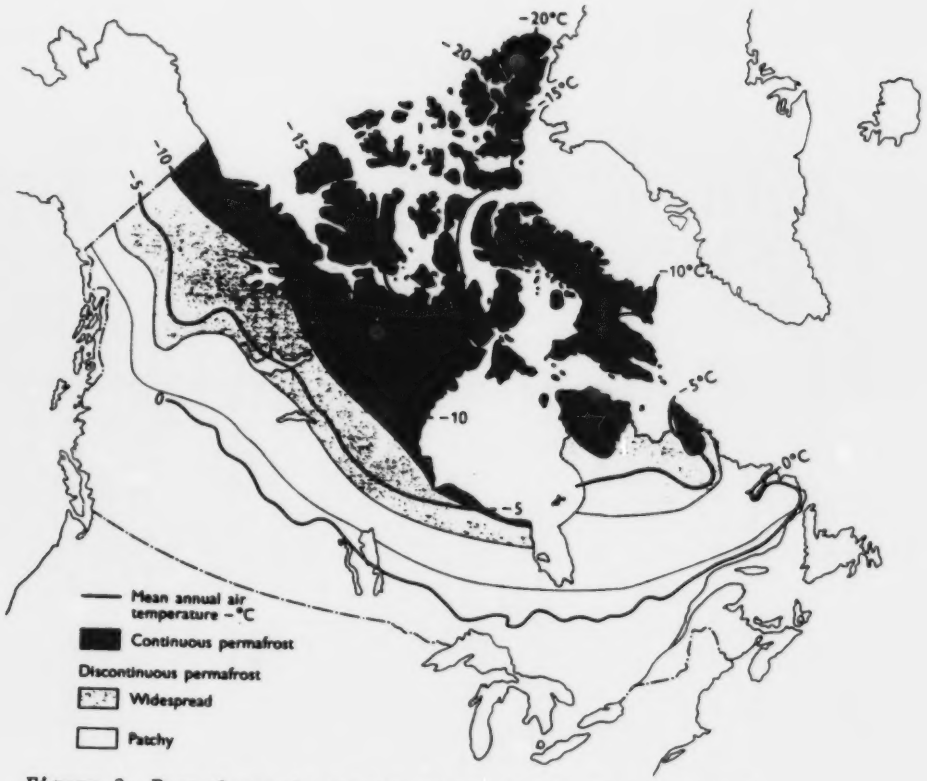


Figure 2. Permafrost in Canada (after R.J.E. Brown, 1978b).

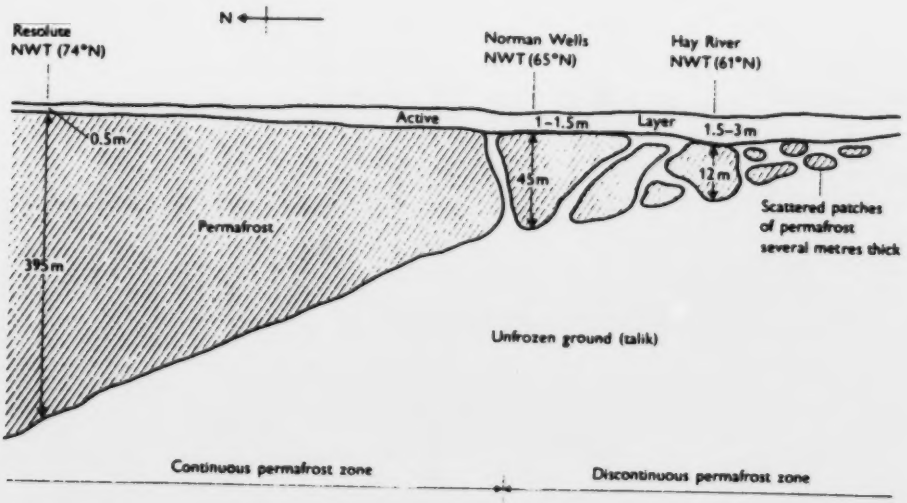


Figure 3. North-South Vertical Profile of Permafrost in Canada Showing Decreasing Thickness Southward and in Relation to Continuous and Discontinuous Permafrost Zones (after R.J.E. Brown, 1970,8, Figure 4).

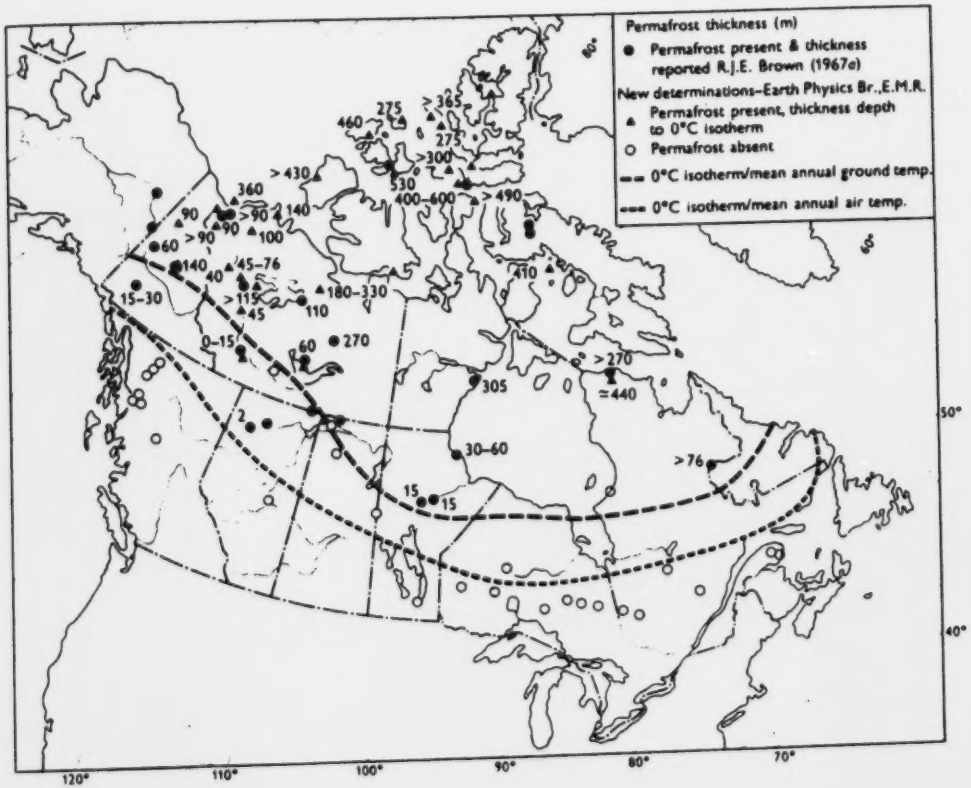


Figure 4. Permafrost thickness and mean annual air and ground-surface isotherms in Canada (after Judge, 1973a, 38, Figure 3).

THE NATURE OF CRYOSOLIC SOILS IN MANITOBA

Cryosolic soils, by the Canadian System of Soil Classification (CSSC, 1978), have permafrost and/or subsurface soil temperatures less than 0°C within 1 meter of the surface or within 2 meters if more than one third of the soil pedon has been strongly cryoturbated as indicated by disrupted, mixed or broken horizons. They are usually associated with patterned ground.

Organic Cryosols

In Manitoba Mesic and Fibric Organic Cryosols are by far the most extensive group of Cryosolic soils in the province (Table 4). They comprise approximately 11.9 million ha or 76 percent of these soils and are associated with a variety of organic landforms (Figures 5, 6 and 7). In descending order of frequency they are found on peat plateaus in all zones; on bog veneers (peat deposits <1 meter thick) in the northern part of Zone 2 and throughout Zone 3; polygonal peat plateaus, peat plateaus and fen ridges in Zones 3 and 4.

Typically Organic Cryosols are 2.5 to 3.5 meters thick, having a cap of somewhat decomposed Sphagnum or forest peat (60-85 percent rubbed fiber); extremely acid (pH 4.0 to 3.5); high organic carbon content (50 to 58 percent). Their surface tier is usually underlain by moderately well decomposed, mesic brown moss and/or sedge peat (10-40 percent rubber fiber content); very strongly acid to extremely acid (pH 5.0 to 4.3); high organic carbon content (51 to 57 percent). Active layers are shallow ranging from 50 to 70 cm in depth and except in the case of thin bog veneers do not extent below the peat layer. Subsurface soil temperatures are usually slightly below 0°C. However, frozen substrate temperatures, ranging from 0° to -5°C, have been recorded in peat polygon terrain near Churchill (L. Dredge, 1979). While Organic Cryosols appear to be in equilibrium with current climatic conditions in the Hudson's Bay Lowland section of Zone 4, as evidenced by the lack of fen-like collapse scars in peat plateaus, they do not seem to be so in Zones 2 and 3 where fen collapse scars are of widespread occurrence.

Turbic Cryosols

Turbic Cryosols comprise approximately 2.8 million ha or approximately 18 percent of Cryosols. They occur mainly in Zones 3 and 4. The most extensive area of these soils have developed on very strongly acid, bouldery, loamy sand glacial till so typical of the Canadian Shield northwest of the Hudson's Bay Lowland. These well drained, strongly cryoturbated mineral soils have deep active layers (>1.5 to 2 m) and are associated with non-sorted circles and stripes. They occur less commonly on poorly drained lowland polygons and turfy hummocks in the northern section of Zone 3 and in Zone 4. Loamy to clayey textured, well to imperfectly drained Orthic Turbic Cryosols comprise approximately 300,000 ha or about 2 percent and occur in the northern section of former Glacial Lake Agassiz basin located in Zone 3. These strongly cryoturbated soils showing weak eluvial A horizon and illuvial B horizon development have distinctively shallower (50-70 cm) active layers or thaw layers than their sandy counterparts. Both types in the northern section of Zone 3 and Zone 4 appear to be in equilibrium with current climatic conditions. Soil temperature

Table 2. Extent of Cryosolic Soils in Manitoba

	Total Area Zone (000 ha)	% Total Land	Total Area Cryosols (000 ha)	% Zone
Zone 1	17,857.8	33	-	-
Zone 2	11,114.0	20	1,376.3	12
Zone 3	17,910.2	33	8,684.123	48
Zone 4	7,918.0	14	5,509.6	70
TOTAL	54,800.0	100	15,570	28

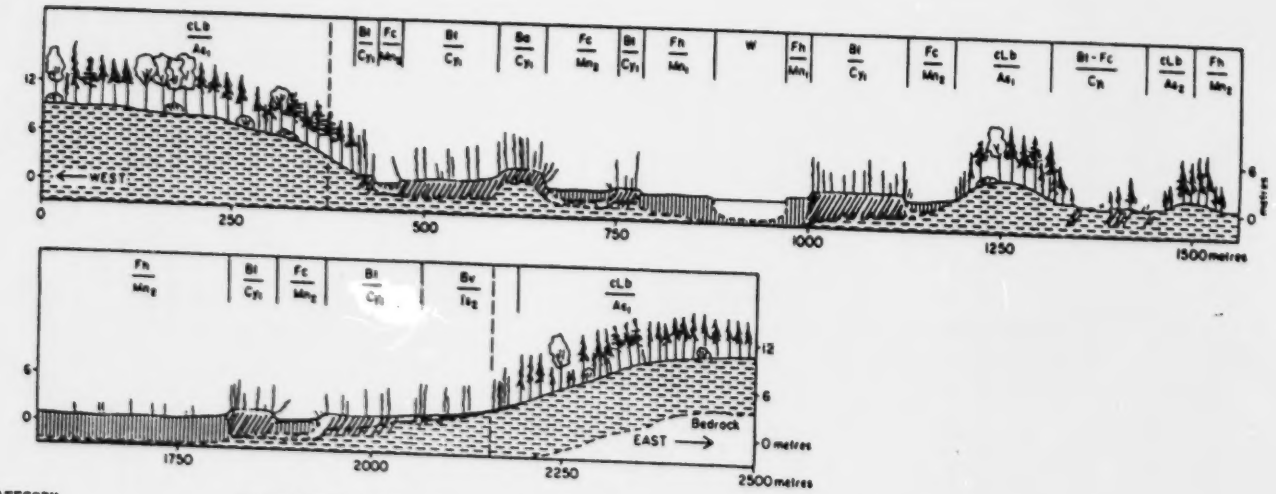
Table 3. Climatic Parameters*

Zone	Mean Annual Air Temp. ^{o}C	Degree Days Above $0^{o}C$	Mean Annual Precip. (mm)	Thaw Period Precip. (mm)
1 (Wpg. A)	2.2	2770	526	400 (76)
(Wabowden)	-2.2	1998	464	316 (68)
2 (Thompson A)	-3.9	1770	542	310 (57)
(Lynn Lake)	-4.0	1823	502	282 (56)
3 (Gillam)	-5.2	1644	485	245 (50)
(Brochet)	-4.9	1692	427	260 (61)
4 (Churchill)	-7.2	1151	402	207 (51)

*AES Summaries 1951-81

Table 4. Distribution of Cryosolic Soils by Zone and Dominant Soil Material

Soil Type	Zone 1	Zone 2	Zone 3	Zone 4	Tot.	%
	Area in ha x 10^{6}					
Mesic and Fibric Organic Cryosols	-	1.4	6.1	4.4	11.9	(76.2)
Orthic Turbic Cryosols - Sandy	-	-	1.5	1.0	2.5	(16.2)
- Clayey	-	-	0.3	-	0.3	(1.7)
Orthic & Gleysolic Static Cryosols						
- Sandy	-	-	0.1	-	0.1	(0.5)
- Loamy	-	-	0.3	0.1	0.4	(2.4)
- Clayey	-	0.01	0.5	-	0.5	(3.0)
TOTAL	-	1.4	8.8	5.5	15.7	(100)



TEXTURAL CATEGORY
(placed before landform class)

c clayey
l loamy
s sandy

GENETIC MINERAL LANDFORM CLASS

A alluvial
C colluvial
E eolian
G glacio-fluvial
L glacio-lacustrine
M morainal
W marine
U undifferentiated

MORPHOLOGY and SURFACE FORM CATEGORY
(placed after landform class)

p plain
h hummocky
u undulating
m rolling
d drumlinized
k kettled
r ridged
t terraced
a apron
Δ delta
f fan
b blanket
v veneer

GENETIC ORGANIC LANDFORM CLASS AND CATEGORY

B Bog

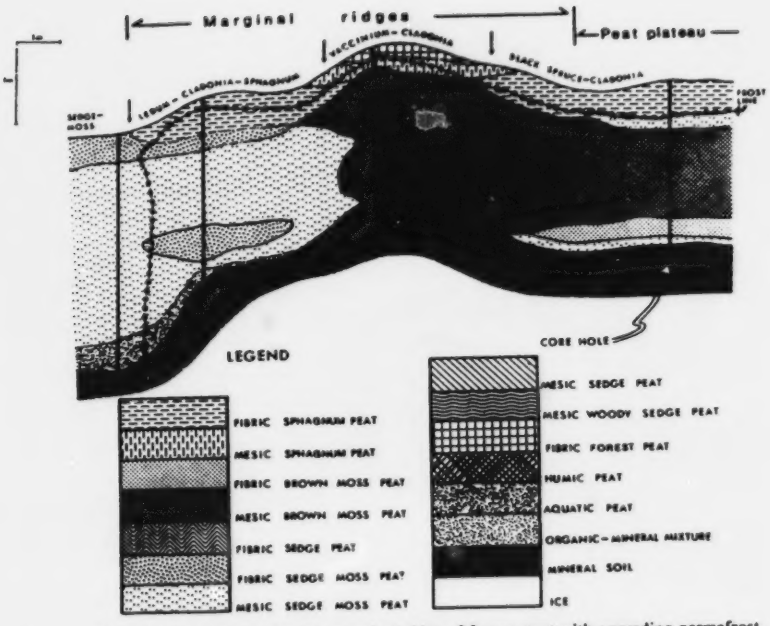
a palsa
b bowl bog
f flat bog
l blanket bog
m peat mound
p bog plateau
t peat plateau
v bog veneer
y polygonal peat plateau

F Fen

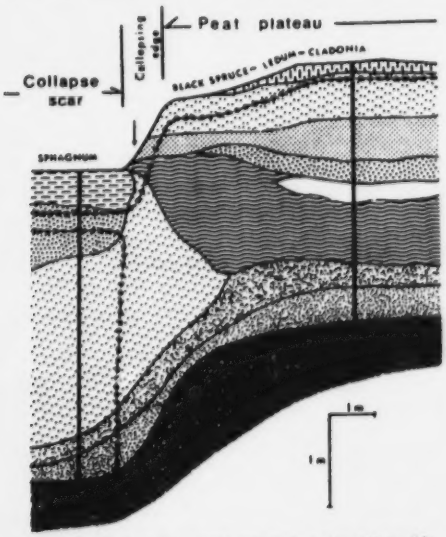
c collapse scar
f floating fen
h horizontal fen
l sloping fen
m minerotrophic palsa
p patterned fen

S Swamp

Figure 5. Cross-section of the clayey lacustrine and Organic deposits showing frozen peat plateaus with fen collapse scars and bog veneers, typical of soil landscapes in Zone 2 and 3 (after H. Veldhuis, 1981).

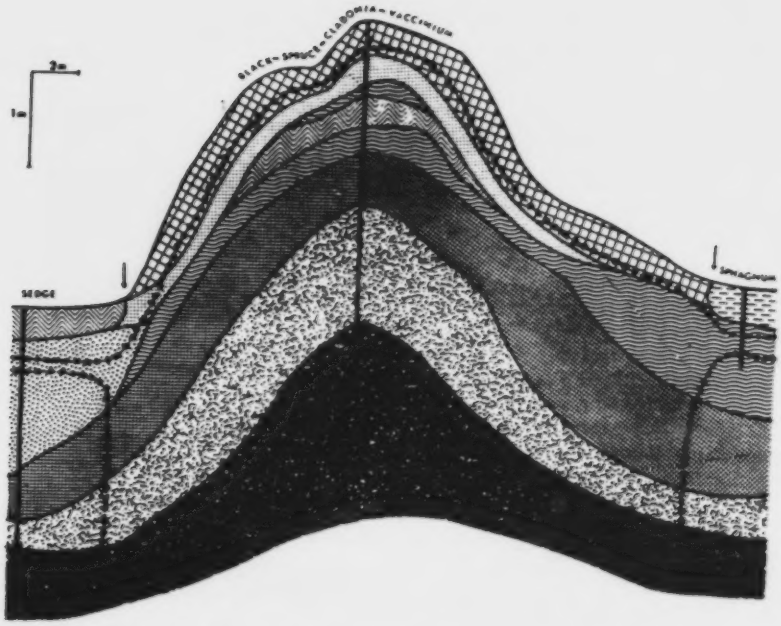


Edge of peat plateau, showing marginal ridge of frozen peat with aggrading permafrost.

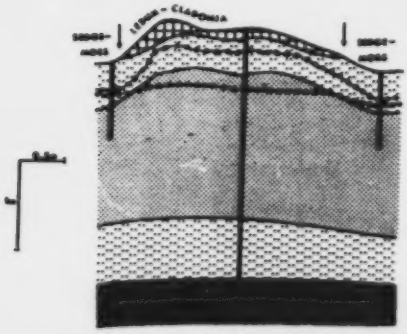


Peat plateau with collapsing edge. Note thin, seasonally-frozen peat in wet depression.

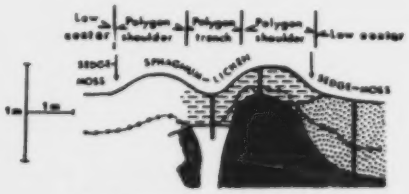
Figure 6. Detailed cross-sections of a peat plateau, palsa, fen ridge, low center polygon and a high center polygon (after Zoltai and Tarnocai, Figures 2, 3, 5, 6, 7, 8, 1975).



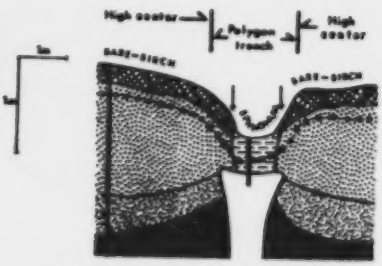
Cross section of a palsa. Note thin seasonally-frozen peat layer at the base of palsa, found at the time of survey.



Cross section of a fen ridge. Note thin seasonally-frozen peat layer in wet fen.



Cross section of polygon trough of a low center polygon.



Cross section of a high center polygon.

Figure 6 (continued).

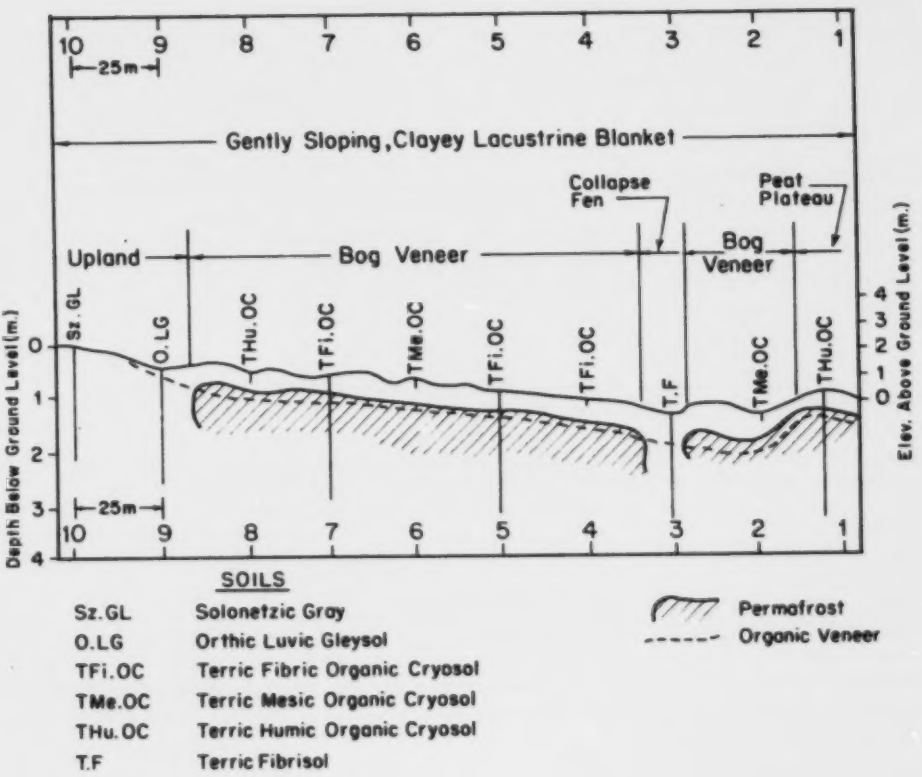


Figure 7. Cross-section of a Bog Veneer (Mills and Veldhuis, 1984).

profiles of frozen substrata in both the sandy glacial till and clayey lacustrine sediments are usually slightly less than 0°C.

Associated very strongly acid Eluviated Dystric Brunisolic soils in Zones 3 and 4 and which occur in all zones do not appear to have been greatly affected by significantly shortened thaw season, reduced mean annual precipitation, lower mean annual air temperatures and resulting reduced biological activity. Illuvial B horizons of these Brunisolic soils contain similar amounts of amorphous Fe and Al, approximately 0.2 to 0.3 percent, as those in Zones 1 and 2.

The mineralogical composition of the fine clay fraction of both the loamy till and the lacustrine sediments of Zones 3 and 4 is comprised dominantly of illite clay, significantly different than those of Zone 1 and southern section of Zone 2 where montmorillonite is codominant with illite (P. Haluschak, 1985). While it might be tempting to speculate that this difference is due to significant differences in climate, the more probable explanation is that illite is the predominant fine clay mineral derivative of granitoid rocks of the Canadian Shield.

Static Cryosols

Static Cryosols comprise approximately 1 million ha or about 6 percent of the Cryosols in the province. Their distribution in the landscape is difficult to discern, since they are not associated directly with any particular landform surface expression or position in the landscape. Gleysolic Static Cryosols developed on both the sandy glacial till deposits in Zone 4 and the loamy to clayey deposits of former Glacial Lake Agassiz in Zones 2 and 3 are probably dominant over well drained Orthic types. Many appear to be associated with the thin Terric Organic Cryosols that are associated with bog veneer landforms so prevalent in Zone 3. In morphological characteristics Gleyed Static Cryosols are very similar to closely associated Terric Fibric and Terric Mesic Organic Cryosols. Well drained soils, associated with Turbic Cryosols, have morphology similar to Eluviated Dystric Brunisols differing from them in having permafrost within 1 meter of the surface.

Seasonally Frozen Soils

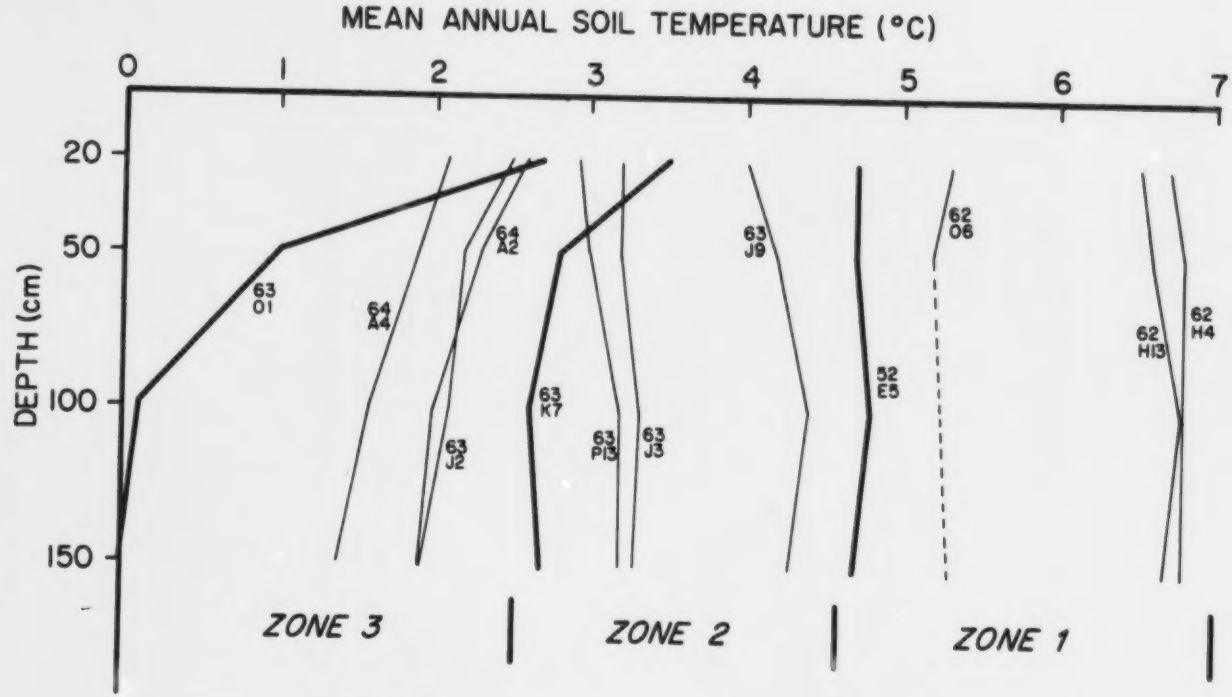
The soils of all zones not having permafrost are affected by seasonal frost action processes. However, these processes are secondary to the dominant soil forming processes in each zone. Maximum depth of seasonal frost penetration is approximately 1.5 to 3 meters depending on local variation in snow and vegetative cover and only persists through the winter months. Saturated medium to fine textured mineral soils and organic soils exhibit well bonded or cemented soil particles. Ice crystals are usually visible as thin ice lenses and veins. Unsaturated soils are poorly bonded and ice crystals are not readily visible. Features of past, more intensive frost heaving and cracking as manifested by relic earth hummock or ice-wedge casts associated with polygons are rare in Zones 1 and 2. However, varved lacustrine deposits and intersecting ice-drift grooving are widespread in deposits associated with former Glacial Lake Agassiz basin. Pedons of Eluviated Dystric Brunisols and Grey Luvisols which are common to all zones exhibit normal horizon development and lack evidence of former cryoturbation.

Table 5. Organic Soil Parameters in Zones 1, 2 & 3

Profiles	Hor.	Depth cm	Rubbed Fiber %	pH	Org. C %
S. Junction	Of1	0-10	62	3.8	55.0
52E-5	Om1	10-20	14	7.1	47.2
Zone 1	Om2	20-140	8	6.7	54.4
	Oh1	140-310	2	7.1	57.5
	IIAhkg	310-320	-	7.2	28.7
Reed Lake	Of	0-15	62	6.7	39.6
63K-7	Om1	15-35	32	6.6	52.9
Zone 2	Om2	35-125	32	6.0	51.7
	Ckg	125-200	-	7.6	-
Joey Lake	Of1	0-15	44	3.4	54.3
630-1	Of2	15-27	80	3.4	57.6
Zone 3	Of3	27-40	88	3.8	53.0
	Om1	40-75	36	4.3	51.0
	Omz1	75-90	34	4.5	53.0
	Omz2	90-180	26	4.7	55.0

Table 6. Soil Chemical Parameters of Selected Eluviated Dystric Brunisols and Orthic Turbic Cryosols from Southern Man. (Zone 1) and Northern (Zones 3 & 4) Manitoba

Profiles (nos.)	Depth cm	Texture	pH	Pyrophos. Ext. Fe + Al %	Org. C %	Domin. (.2 u) F. Clay Min.
1-Pointe du Bois (7)						
L-H	5-0		4.9		27.9	
Ae	0-5	LS	4.7	0.1	1.1	
Bm	5-29	LS	4.8	0.2	0.7	
C	80-100	LS	5.1	0.1	0.1	Mont.-IL
3-Munroe L. (3)						
L-H	15-0		3.3		34.2	
Ae	0-7	LS	3.8	0.1	1.2	
Bm	7-20	LS	4.4	0.3	1.6	
C	75-100	LS	5.2	0.1	0.2	IL
4-Nejanilini L. (2)						
L-H	4-0		4.1		16.4	
Ae	0-4	LS	4.6	<0.1	0.4	
Bmy	4-13	LS	4.7	0.2	0.8	
C	100+	LS	5.5	<0.1	0.2	IL



WELL DRAINED CLAY SOILS

62H4	Fort Garry	63J9	Wabowden
62H13	Letellier	63P13	Thompson
6206	Homebrook	64A2	Orr Lake
63J2	Kiski Creek	64A4	Split Lake
63J3	Minago		

ORGANIC SOILS

52E5	South Junction
63K7	Reed Lake
6301	Joey Lake

Canada - Manitoba Soil Survey, Jan. '86

Figure 8. Mean Annual Soil Temperature Profiles for Zones 1, 2 and 3.

DATA BASE REQUIREMENTS FOR MANITOBA'S NEW LAND ASSESSMENT SYSTEM

R. Hamm
Manitoba Municipal Affairs

Definition of Assessment

Assessment is the mass appraisal of property for the purpose of establishing a tax base. It is a method of distributing the tax load equitably among all tax-payers and therefore the value relationship of one property to another is of paramount importance.

Branch History

The Provincial Municipal Assessment Branch was established by statute in 1947 for the purpose of providing uniform assessments on a provincial basis. At that time each municipality hired its own assessor, usually on a part-time basis, and there were no uniform standards. In effect, each municipality operated at its own level of value and inter-municipal levies varied from one unit to another. The formation of the Branch was intended to alleviate some of these problems.

Originally Branch administration came under the jurisdiction of The Municipal Act but in 1970 The Municipal Assessment Act was passed, and this Act, with various amendments, still governs most Branch activities.

The legislation governing all land assessment reads as follows:

> Section 29(1) "Lands apart from buildings shall be assessed at their value; and in determining value, the assessor shall consider, amongst other things, the advantages and disadvantages of location, the quality of the soil, the annual rental value which, in his judgment, the lands are reasonably worth for the purposes for which they may be used, the value of any standing timber and such other considerations as the Provincial Municipal Assessor directs."

These provisions apply to all land, whether it be agricultural or residential, commercial or recreational, public or private. Over the years courts have defined "value" to mean market value, and specific items that have to be considered are location, soil quality, rental value and standing timber.

By 1950, assessment rates had been established for the agricultural areas of the province, based on the reconnaissance level of soil surveys. There were approximately 190 Soil Associations and Associates with additional texture separations for a total of nearly 350 individual rates.

The rates for the major associations were obtained from yield data for the period from 1927 to 1947, together with estimates of production costs to arrive at a net return. This was then capitalized into a value per acre. Rates for minor associations, covering smaller areas, were derived from comparisons and interpretations. Generally, clay soils had shown the best yields and were rated the highest, with sandy soils considered to be relatively worthless.

Individual quarters were rated on the basis of differences in topography, erosion, drainage, texture, stones, salinity, structure and permeability, cultural pattern, and location. The base rates represented the optimum condition for that soil and discounts were applied for any of the above factors noted on each parcel.

After the first round of assessments were completed land sales were analyzed and it was found that the level of assessment was approximately 45% of market value during the mid-fifties. Since then over-all rates have been increased and from the mid-sixties to the present relative rates on some of the lighter-textured soils have been increased to reflect relative changes in their value. These changes are due to different weather patterns, changes in technology and farming practices, and the introduction of new crops.

Assessment indexes are now based on the original yield data analysis modified by more recent sales data, so that each soil is assessed at approximately the same level of market value. The problem currently is that our data base is sketchy at best in terms of soil characteristics and making adjustments to relative ratings where some of the soil factors are unknown may occasionally result in rates that do not quite fit the pattern.

In 1979 the Assessment Review Committee was appointed to investigate the entire assessment process in Manitoba. This committee came up with approximately 165 recommendations and as a result the Branch has been re-organized and specific duties have been assigned to various staff members to examine the implications and expedite implementation of the recommendations.

Two of the specific suggestions made by the committee were to revalue all property annually and to have the level of assessment at or near current market value levels.

Annual revision requires mechanization. To meet this requirement a needs analysis has been completed and testing will begin later this year on a completely computerized rating system for agricultural land. This will give us the capacity to revalue all or any land very quickly, and at the same time will provide us with the tools required to analyze various soil characteristics to determine their effect on value.

The recommendation on current value levels is intended to provide assessments that are more easily understood by tax-payers. In order for us to cope with that increased awareness, we need to be fully informed on all details of each property. For agricultural land this involves a complete cataloguing of all the characteristics of each soil, particularly those that affect productivity and value. With this in mind we are redesigning the system so that the terminology used by the assessor will be the same as that used in soil reports, thereby ensuring that the same factors are accounted for by each group. The only variable then will be the measurement of the area and the severity of the problem encountered on any individual parcel.

At present we are using approximately 350 different rates. With the detailed surveys now available, over 1,000 additional series will have to be rated and indexed at rates anywhere from $400 to $3,000 per hectare. To arrive at these rates, detailed analyses will have to be carried out to account for all factors that affect value, and all differences will need to be documented.

Detailed surveys are making many of the separations we require in terms of texture, drainage, salinity, topography, stones, erosion and so on. Currently we are using a general index for an association and we then discount from that base rate for various detrimental factors to arrive at the assessment for an individual parcel. Using the detailed survey, most of the detrimental factors will be accounted for in the base rate and the degree of discounting should be limited to a fairly narrow range.

The following outline is a brief (and incomplete) listing of various items that will be required for analyses:

1. Soil Classification - to relate current rates to new series, and to develop new rates where required.
2. Climatic zones - to attempt to account for different values on similar soils in different locations.
3. Agricultural capability ratings and productivity ratings - the factors involved and how they relate to value.
4. Parent material - how this influences fertility and productivity.
5. Method of deposition in relation to value.
6. Depth of profile related to productivity.
7. Texture and variations through the profile.
8. Drainage patterns.
9. Water retention capacities.
10. Depth to water table.
11. Permeability.
12. Organic matter content.

13. Estimated area by series.
14. MCIC ratings.
15. Target yield categories.
16. Miscellaneous factors affecting value.

Analysis of this data should provide a detailed and reasonably dependable rating system that can be used as a starting point for the development of assessment rates.

Undoubtedly there will be differences between ratings established through physical comparisons and economic factors, as well as Crop Insurance, since each system was designed for specific purposes, but with adequate inter-action and awareness of the individual requirements of various rating systems these variations can be explained. With appropriate programming and analytical detail the mass of information available can be handled and can become very useful.

SMALL SCALE MAPS OF WATER EROSION POTENTIAL AND SALINITY FOR MANITOBA

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SOILS AND GEOLOGY SENSITIVITY MAPPING FOR ACID RAIN IN WESTERN CANADA

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INTRODUCTION

In Canada the mapping of terrestrial ecosystems for their sensitivity to the potential effects of acid rain or the long range transport of air pollutants (LRTAP) was initiated in the 1980's. Prior to 1980 little information was available on the potential impacts of acidic deposition on terrestrial systems, however, it was recognized that inherent variability of natural soil and geologic material would alter the fate of incoming acidic compounds from atmospheric processes.

In Eastern Canada initial sensitivity mapping was completed in 1983 as part of the Memorandum of Intent, MOI (Bangay and Riordan 1983). In 1981, the need for compatible mapping was recognized in Western Canada and was addressed by the Consultative Committee - Western Canada Long Range Transport of Air Pollutants. This committee composed of deputy ministers from the provinces of British Columbia, Alberta, Saskatchewan and Manitoba together with its Technical Committee coordinates monitoring, research and other acid rain related activities in the west.

The Consultative and Technical committees appointed a Coordinating Committee for Soil and Geology Sensitivity Mapping in late 1981 with representation from each of the western and northern jurisdictions. This group was responsible for reviewing previous mapping efforts in Eastern Canada and for establishing methodologies and criteria to complete compatible sensitivity mapping in the west. Each provincial and territorial jurisdiction was responsible for completion of mapping in their respective area.

It was recognized that objectives, definitions and uses of sensitivity maps for terrestrial ecosystems would vary. Most commonly one or more terrestrial components are targetted for sensitivity rating and mapping whether it is soils, geology, forest or agricultural productivity. A simple sensitivity map is unlikely to serve all purposes.

In compliance with the appointed mandate from the Consultative Committee, the provincial and territorial jurisdictions of western Canada agreed to develop two maps at a scale of 1:2,000,000 in the prairie provinces and 1:5,000,000 for the Yukon and Northwest Territories. This would provide a logical compromise based on the best available information in each of the respective areas. Following completion of individual jurisdictional maps a composite at a scale of 1:5,000,000 was to be prepared to provide a regional perspective for Western Canada.

OBJECTIVES

(1) POTENTIAL OF SOILS AND BEDROCK TO REDUCE THE ACIDITY OF INCOMING ACIDIC DEPOSITION

To identify and rate soils, surficial and bedrock geology for their potential to reduce precipitation acidity prior to its entry into the aquatic regime. This is based on the premise that soils and geology information provides the best indication of the long term capacity of watersheds to buffer acidic deposition.

(2) SENSITIVITY OF SOILS TO ACIDIC INPUTS

To identify and rate soils to changes in physical, chemical and biological properties to reflect possible effects to forest or agricultural productivity. Soil sensitivity being defined as an expression of the respective susceptibilities of different soils to changes in one or more of the following: soil acidification and pH reductions; mobilization of exchangeable bases; and solubilization of aluminum in response to a given input of acidity.

METHODOLOGIES - WESTERN CANADA

The first task of the Soil and Geology Coordinating Committee was to assemble and review soil and geology mapping information available as a data base in each of the four western provinces, the Yukon and the Northwest Territories. A report was released in late 1981 (Wotton, 1981) and was followed by a second report outlining general agreements and outstanding issues relative to proceeding with a coordinated approach to sensitivity mapping (Wiens, 1982).

During 1983 and 1984 the committee reviewed sensitivity mapping efforts in Eastern Canada, defined sensitivity classification criteria and established acceptable sensitivity classes. Criteria and methodologies were initially based on those employed in Eastern Canada (Bangay and Riordan, 1983, Cowell, et al., 1981, Lucas and Cowell, 1984, Shilts et al., 1981, Wang and Coote, 1981). However, variation in available data base and topographical features in the west necessitated some modification to these methodologies to ensure compatible mapping acceptable to all jurisdictions of Western Canada (Wiens, 1983).

SOIL AND BEDROCK SENSITIVITY CRITERIA

Methods and criteria developed for Eastern Canada through the MOI exercise were adopted where terrain characteristics are approached on a holistic base and the result is the map, "The Potential of Soils and Geology to Reduce the Acidity of Incoming Acidic Deposition."

Soil and geologic information were recognized as the best indicators of the long term capacity of watersheds to buffer acidic deposition. This map was therefore developed for interpretation of sensitivity to aquatic systems. The rating of potential to reduce

Table 1: Terrestrial Factors and Associated Criteria for Determining the Potential of Terrestrial Ecosystems to Reduce Acidity of Atmospheric Deposition (Modified after Cowell et al. 1981).

TERRESTRIAL FACTORS	POTENTIAL TO REDUCE ACIDITY OF ATMOSPHERIC DEPOSITION		
	HIGH	MODERATE	LOW
Soil Chemistry			
i) Exchangeable Bases (meq/100g)	>15	6 to 15	<6
Surrogates:			
(a) Family Particle Size and pH in water.	clayey, >pH 5.0 loamy, >pH 5.5 all calcareous soils	clayey, pH 4.5 to 5.0 loamy, pH 5.0 to 5.5 sandy, >pH 5.5	clayey, <pH 4.5 loamy, <pH 5.0 sandy, <pH 5.5
(b) Texture	clay, silty clay, sandy clay (>35% clay)	silty clay loam, clay loam,	silt, sandy loam, loamy sand, sand (<10% clay)
(c) Cation Exchange Capacity	>25 meq/100g	10 to 25 meq/100g	<10 meq/100g
ii) SO_4^{-2} Adsorption Capacity low sulphate adsorption:	low organic matter AND high Al_2O_3 and/or $Fe_2O_3 + Fe_3O_4$ content	high sulphate adsorption: ———	high organic matter AND/OR low Al_2O_3 and/or $Fe_2O_3 + Fe_3O_4$ content
Soil Depth (cm)	>100	25 - 100	<25
Soil Drainage	poor	imperfect to well	rapid
Landform Relief	level	rolling	steep
Vegetation	deciduous	mixed	coniferous
Vegetation Cover	continuous (>60%)	discontinuous to sparse	sparse to barren (<20%)
Underlying Material			
i) Parent Material	carbonate bearing	non-carbonate bearing	non-carbonate bearing
ii) Bedrock Material	limestone, dolomite, and metamorphic equivalents, calcareous clastic rocks, carbonate rocks interbedded with non-carbonate rocks	volcanic rocks, shales, greywackes, sandstones, ultramafic rocks, gabbro, mudstone, metaequivalents	granite, granite gneiss, orthoquartzite, syenite

acidity was based primarily on bedrock characteristics, on a combination of bedrock and soil characteristics, and/or primarily on soil characteristics.

The criteria for rating soils and bedrock is found in Table 1. The rating system developed is based on the assumption that water moving through the terrestrial system may contact soil, surficial geologic material and bedrock on its passage to surface water systems and each component is rated respectively. Knowledge of soil properties such as pH, exchangeable bases, cation exchange capacity, texture and underlying bedrock type are incorporated into rating each map unit.

SOIL SENSITIVITY CRITERIA

Three principal soil chemical processes were accepted to evaluate the sensitivity of acidic deposition to terrestrial ecosystems: soil acidification and pH reduction, base cation loss, and aluminum solubilization. Individual sensitivities to these internal soil characteristics were evaluated and combined into a single interpretation for evaluation of agricultural, forest and natural vegetation productivity.

The criteria for separately rating sensitivity of soils is found in Table 2 and several points should be emphasized in interpretation. The criteria attempt to integrate or combine soils and geology information in a systematic way to arrive at a single sensitivity rating. Adoption of these criteria require that each map unit be defined for characteristics of soil chemistry (exchangeable bases or surrogates), soil depth, bedrock exposure and bedrock type. This definition may be attained directly from source maps or indirectly from inference.

In an attempt to have the interpretive map representative of forest and agricultural sensitivity the following assumptions regarding sensitivities of soil properties were adopted:

- High sensitivity for already acid soils, or mineral soils with a low cation exchange capacity (CEC). It is assumed that the soils will have a potential for high levels of Al which will cause decreased productivity.

- High sensitivity for soils sensitive to base cation loss where the amount of base is initially low (i.e. low CEC and/or low initial pH, therefore low base saturation). Although soil sensitivity to base cation loss is significant, it must be considered in combination with CEC and initial pH.

MANITOBA SENSITIVITY MAPPING

The Environmental Management Division of the Province of Manitoba cooperatively addressed the task of sensitivity mapping in the province with the Canada-Manitoba Soil Survey. Both agencies

Table 2 : Criteria for Rating the Sensitivity of Soils to Acidic Deposition*

CEC	pH	Base Loss	Acidification	Al Solubilization	Overall Sensitivity
<6	<4.6	H	L	H	H
	4.6-5.0	H	L	H	H
	5.1-5.5	H	M	H	H
	5.6-6.0	H	H	M	H
	6.1-6.5	H	H	L	H
	>6.5	L	L	L	L
6-15	<4.6	H	L	H	H
	4.6-5.0	M	L	H	M
	5.1-5.5	M	L-M	M	M
	5.6-6.0	M	L-M	L-M	M
	>6.0	L	L	L	L
>15	<4.6	H	L	H	H
	4.6-5.0	M	L	H	M
	5.1-5.5	M	L	M	M
	5.6-6.0	L	L-M	L-M	L
	>6.0	L	L	L	L

* Sensitivity Code: H - High, M - Moderate, L - Low

worked in advisement with the Geological Services Branch, Department of Energy and Mines, Province of Manitoba. The following sources of information were used:

1. Base Map - Generalized Soil Landscape Map with Extended Legend.
2. Soil Survey Reports, Maps and Analytical Data.
3. Soil Test Information on pH, Carbonate and Texture.

(i) SOIL AND GEOLOGY SENSITIVITY MAPPING

Rating of map units for potential of soils and bedrock to reduce acidity of incoming acidic deposition was determined by using criteria provided in Table 1. The influence of soils and bedrock to a depth of 2 meters was considered in rating map units into classes.

A low potential to reduce acidity was assigned to soils that are generally acidic, coarse textured and have a low content of exchangeable bases. Organic (bog) soils were included in this class because of their acidic nature and low base status. Bedrock containing non-carbonate bearing rocks was also placed into the low class. Soils which are medium textured, free of carbonate and have a moderate content of exchangeable bases were placed in the moderate class.

Soils, generally high in clay and exchangeable bases and/or soils with carbonates were rated as having a high potential to reduce acidity. Bedrock containing limestone, dolomite and other carbonate bearing rocks were also rated to have a high potential to reduce acidity.

(ii) SOIL SENSITIVITY MAPPING

The rationale and criteria adopted by the Coordinating Committee was followed for the interpretation of the Manitoba data base. The generalized soil landscapes map and legend containing 325 delineations, provided the base. Larger map units were derived from information on soil development, surface texture and carbonate level. These larger map units were evaluated by examining CEC, base status and pH values from analytical data of many sites. Each map unit was rated for sensitivity to base soil pH change, cation loss, and aluminum solubility.

Soil sensitivity classes to acidic inputs (i.e. low, moderate, high) were based on a combination of these three ratings. Generally, the properties of the surface 20 cm of soil were most important in preparing the sensitivity classes. Table 3 provides a guide for assigning soil sensitivity classes to map units by soil development and surface texture for the province. Map units containing dominant and sub-dominant components are considered in the class rating.

In general, the non-sensitive or low class to acidification is comprised of map units in which soils are high in clay,

Table 3: Guide for Assigning Soil Sensitivity Classes in Manitoba.*

	HIGHLY SENSITIVE	MODERATELY SENSITIVE	LOW SENSITIVE
(i)	DYSTRIC BRUNISOLS (S, LS, associated with acid bedrock and organic soils)	EUTRIC BRUNISOLS (S, LS, and SL with carbonate free surface)	EUTRIC BRUNISOLS (L, high carbonate in subsurface)
(ii)	ORGANICS (BOG) (associated with acid bedrock, organics (fen) and luvisols)	ORGANICS (FEN) (associated with organic (bog) and luvisols)	
(iii)	CRYOSOLS (LS, associated with dystric brunisols)		
(iv)		BLACK CHERNOZEMS (Gr. S, S, LS, well drained)	BLACK CHERNOZEMS (SL, L, CL and C carbonates at or near the surface)
(v)		REGOSOLS (Gr. S, S, LS, well drained, eolian)	REGOSOLS (L, CL and C surface textures)
(vi)		DARK GREY CHERNOZEMS OR LUVISOLS (S, LS and SL surface texture)	
(vii)		GRAY LUVISOLS (LS, SL, L and CL and northern clay textured luvisols associated with organic soils and/or acid bedrock)	
(viii)			BLACK SOLONETZIC (L and CL surface textures)
(ix)			GLEYSOLS (all surface textures)
(x)	BEDROCK (ACID) (mainly non carbonate bearing rocks, i.e. granite, granite gniess, orthoquartzite, syenite)		BEDROCK (CARBONATE) (mainly limestone, dolomite and meta morphic equivalents)

* TEXTURE

S	= Sand	SL	= Sandy Loam
LS	= Loamy Sand	CL	= Clay Loam
Gr. S	= Gravelly Sand	C	= Clay
L	= Loam		

exchangeable bases are greater than 15 meq/100g and pH values are neutral to alkaline. All calcareous soils and carbonate bearing bedrock are placed into this class.

Map units in the moderately sensitive class contain soils with lower amounts of clay, exchangeable bases of 6 to 15 meq/100g and pH values are slightly acidic.

Coarse textured (sand, loamy sand and sandy loam), acidic soils, organic soils associated with coarse textured, acidic soils and/or non-carbonate bearing bedrock were placed into the highly sensitive class.

SUMMARY

The provincial and territorial jurisdictions of western Canada have agreed to produce two soil and geology sensitivity maps at a scale of 1:2,000,000 for Manitoba, Saskatchewan, Alberta and British Columbia and at a scale of 1:5,000,000 for the Yukon and Northwest Territories. A further composite map at a scale of 1:5,000,000 will be developed by the Soils and Geology Coordinating Committee for the entire western and northern regions.

The map "Potential of Soils and Bedrock to Reduce the Acidity of Incoming Acidic Deposition" was developed in a compatible context with sensitivity mapping in eastern Canada. Criteria adopted rate soils, surficial, and bedrock geology for their potential to reduce precipitation acidity prior to its entry into aquatic ecosystems.

The map "Sensitivity of Soils to Acidic Inputs" was developed for interpretation of sensitivity to terrestrial systems and reflects possible effects on forest or agricultural productivity. Three principal soil processes were accepted to evaluate sensitivity: soil acidification and pH reduction, base cation loss, and aluminum solubilization.

In Manitoba soils and bedrock rated as having a low potential to neutralize acid or having a high sensitivity to acidic deposition were found on the east side of Lake Winnipeg and in the northwest corner of the province. These areas were similarly delineated as highly sensitive in the mapping of soil sensitivity.

Note: Copies of Manitoba soil and geology sensitivity maps as well as a detailed report are available through the Department of Environment and Workplace Safety and Health, Province of Manitoba and the Canada/Manitoba Soil Survey, University of Manitoba.

REFERENCES

Bangay, G. B. and Riordan, C. 1983. Memorandum of Intent on transboundary air pollution (MOI). Phase III Working Paper, Impact Assessment Working Group I, Dept. of External Affairs, Ottawa, Ontario.

Cowell, D. W., A. E. Lucas and C. D. A. Rubec. 1981. The development of an ecological sensitivity rating for acid precipitation impact assessment. Working Paper No. 10. Lands Directorate, Environment Canada.

Lucas, A. E. and D. W. Cowell. 1982. A regional assessment of sensitivity to acidic deposition for Eastern Canada. Presented at the Symp. Acid Precipitation. Am. Chem. Soc., Las Vegas, N.V.

Lucas, A. E. and D. W. Cowell. 1984. A regional assessment of sensitivity to acidic deposition for Eastern Canada. In Geological aspects of acid deposition. Ed. O. P. Bricker, Ann Arbor Science, Stoneham, M.A. pp. 113-129.

Shilts, W. W., Card, K. D., Poole, W.H., and Sandford, B. V. 1981. Sensitivity of bedrock to acid precipitation: Modification by glacial processes. Paper 81-14. Geol. Survey of Canada, Ottawa.

Wang, C. and D. R. Coote. 1981. Sensitivity classification of agricultural land to long-term acid precipitation in Eastern Canada. L.R.R.I. Contrib. No. 98. Research Br. Agric. Canada.

Wiens, J. H. 1982. Soil and geology sensitivity mapping in Western Canada - Issues and guidelines. Report on behalf of the Task Gr. on Soils and Geology Sensitivity Mapping. 15 pp.

Wiens, J. H. 1983. Soils and geology sensitivity mapping in Western Canada. Report of June 27, 28 meetings. Victoria, B.C. 30 pp.

Wotton, D. L. 1981. Status of soils and geology sensitivity mapping in Western Canada. Report on behalf of the Coordinating Committee on Soils and Geology Sensitivity Mapping: 47 pp.

GROUNDWATER CHARACTERISTICS AND RESPONSE TO PRECIPITATION OF SELECTED MANITOBA SOILS

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ABSTRACT

Eight soils located in the Swan River area are examined with respect to soil and groundwater characteristics during the 1985 growing season. Characteristics of the soil water regime are described in terms of depth and persistence of periods of saturation. The influence of precipitation events on water tables in these soils is descussed with respect to soil properties and to location in two physiographic areas.

INTRODUCTION

Manitoba Soil Survey reports published since 1967 have included interpretations for selected landuses related to dryland and irrigation agriculture, engineering and recreation. Many of these interpretations depend on soil-water relations which are governed by soil physical properties such as particle size distribution, bulk density, structure and organic matter content. In addition soil-water relations are influenced by shallow water tables associated with those soils which are not freely drained.

The characteristics of the saturated soil zone (water table) have been studied by monitoring shallow water tables as part of ongoing soil survey projects in Manitoba since about 1958. Although some of this information was used to describe soil groundwater conditions in specific mapping projects, much of the data has not been studied in detail because reliable analysis depends on longer term observations.

The national Expert Committee on Soil Survey (ECSS) recently placed a high priority on developing and testing an improved, more detailed classification of soil water characteristics. Current trends for characterizing the saturated soil zone include parameters such as highest and lowest depths to saturated soil and least and greatest duration of persistence of the saturated zone at various depths (Nowland, 1981, Eilers, 1982).

Characteristics of the unsaturated soil zone are dynamic throughout the year and are best estimated by modelling techniques. Where the appropriate soil properties and meteorological data are known, computer models such as EPIC (Erosion-Productivity-Impact-Calculator) have the capability of calculating the yearly pattern of water states. Examples of computed pattern of water states are provided in the report of Standing Committee II, Moisture in Soils, to the United States National Technical Work Planning Conference of the Cooperative Soil Survey (SCS, 1983). In Manitoba a recently developed soil productivity model, (PIXMOD) contains a soil moisture subroutine which predicts available soil moisture at 4 stages in the growth of a wheat crop (Onofrei and Smith, 1985).

Review of available information concerning the physical properties affecting soil water movement, retention and availability indicates deficiencies in the data base for many Manitoba soils.

This lack of data has been addressed recently by the Soil Survey through increased efforts to measure soil physical properties, particularly those affecting available water holding capacity, hydraulic conductivity and infiltration rates (Michalyna, 1984; Michalyna and Haluschak, 1985).

The fluctuation of shallow water tables is currently being monitored by soil survey in a number of Manitoba soils. There is also available considerable historical data collected from shallow groundwater measurements over the past two decades. The main purpose of this presentation is to support current efforts of the national working group on Soil Water Regime to improve and standardize the classification of soil water regimes in Canada. Specifically, the objectives are to:

1. Characterize short-term seasonal groundwater fluctuation associated with selected soils in the Swan River Valley.
2. Demonstrate the application of the proposed Soil Water Regime criteria for classifying the saturated zone and to estimate the properties of the unsaturated zone.
3. Determine the nature of the response of these water tables to precipitation events during the 1985 growing season.

METHODOLOGY

During soil correlation of the Swan Lake map area with the previously published Swan River Soil Map (Ehrlich et. al., 1962) eight benchmark sites were selected to characterize shallow groundwater fluctuation in four major soils in the area. Two soils were selected as representative of each of the Lenswood, Swanford, Valley and Kenville series. One each of the Lenswood, Swanford and Valley soils is located above the Kenville Escarpment in the Swan River Plain and the second soil of each series is located below the Escarpment in the Armit River-Swan Lake Plain. Both Kenville soils are located above the Kenville Escarpment (Figure 1). Each soil was instrumented with a shallow observation well installed to a depth of approximately 3 m. The stratigraphy at each site was recorded during installation of the well. Water table levels were monitored throughout the 1985 growing season. Daily precipitation received at Swan River (A.E.S., personal communication) during this time is assumed to apply uniformly to all sites.

RESULTS AND DISCUSSION

Description of Study Area

The Swan River area consists of several physiographic subdivisions (Figure 1). Elevation and relief differences between the physiographic sections and stratigraphic variation in the associated surficial materials influence surface drainage and regional groundwater characteristics of each subdivision.

The Armit River-Swan Lake Plain (D2.3) occupies a portion of the Manitoba Plain bounded on the west by the prominent Kenville Escarpment at an elevation of about 375 m a.s.l. The Duck Mountain forms the southern boundary and the Porcupine Hills lie to the northwest and west. The surface deposits within this section consist mainly of lacustrine sediments, ranging from sandy to loamy and clayey textures. These deposits are underlain with very strongly calcareous till at shallow depths.

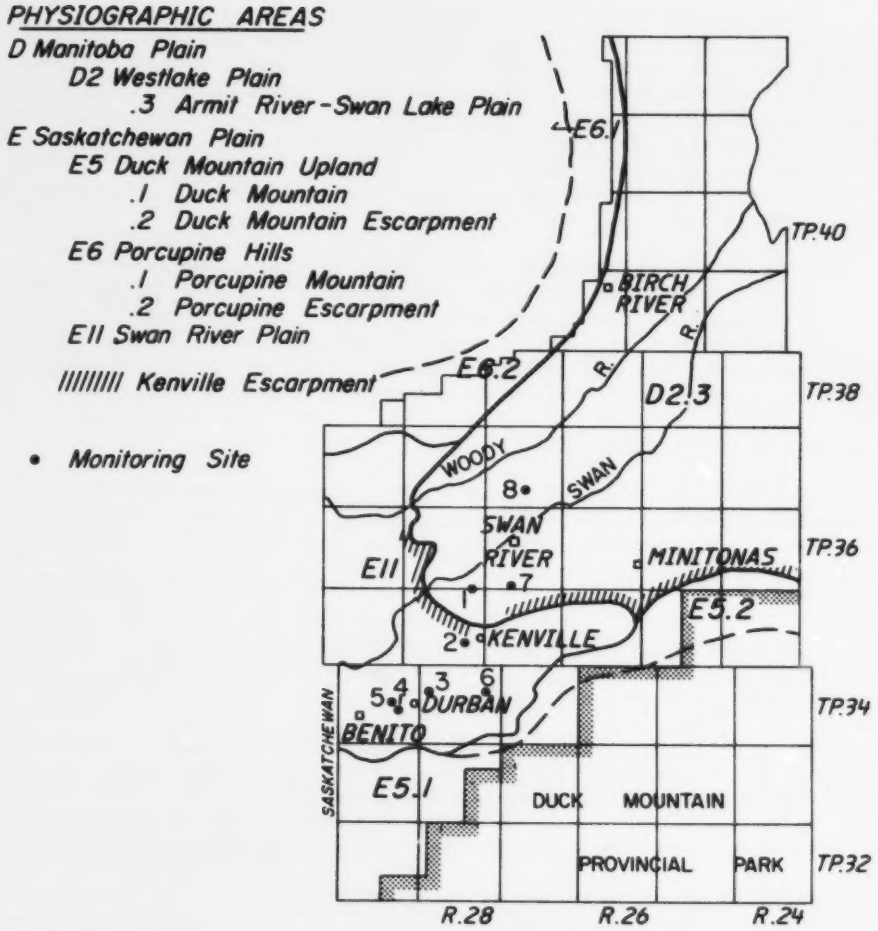


Fig. 1 Physiographic Areas and Location of Well Sites.

The topography ranges from level in the lacustrine areas to gently sloping in the till areas. Most of the Armit River-Swan Lake Plain is imperfectly drained and characterized by relatively shallow depth to groundwater.

The Swan Lake Plain (E11) occurs above the Kenville Escarpment at 375 m a.s.l. and between the Duck Mountain and the Porcupine Hills. Central portions of this section consist of lacustrine sandy, silty and clayey sediments and the peripheral areas are characterized by thin lacustrine veneers overlying glacial till and outcrops of glacial till. Topography is very gently to gently sloping except in areas near the Swan River and the Kenville Escarpment where the land is deeply incised by V-shaped ravines. The soils are dominantly well drained with moderately deep water tables.

The Duck Mountain and Porcupine Hills consist primarily of end moraine and supraglacial deposits with hummocky and hilly topography. Surface drainage is rapid over most of these areas and soil drainage ranges from good to very poor. These uplands serve as regional groundwater recharge sites and influence the hydrology of the adjacent and lower lying Swan River Plain and Armit River-Swan Lake Plain.

Description of Benchmark Sites

Five soils in the Swan River Plain and three soils in the Armit River-Swan Lake Plain were instrumented with shallow observation wells (Figure 1). A Lenswood soil (site 6), Swanford soil (site 3) and Valley soil (site 4) occur in the Swan River Plain. In addition, benchmark sites were established on two Kenville soils (site 2 and 5) also located in the Swan River Plain. Three soils representing the Lenswood series (site 1), Swanford series (site 7) and Valley series (site 8) were instrumented in the Armit River-Swan Lake Plain lying below the Kenville Escarpment.

The stratigraphy of the surficial materials observed at each benchmark site is shown in Figure 2. The sandy Lenswood soils and the coarse loamy Swanford soils are underlain with fine loamy sediments at depths ranging from 1.2 to 2.7 m. The Valley and Kenville soils consist of relatively uniform fine loamy sediments to a depth of 3 m.

The soil characteristics at each site are summarized in Table 1. The Lenswood, Swanford and Valley soils have evidence of gleying in the upper portion of the C horizon and are classified as imperfectly drained regardless of location above or below the Escarpment. Both Kenville soils located above the Escarpment are well drained.

Water Table Fluctuation

Water table observations for the Lenswood A soil (above the Kenville Escarpment) and the Lenswood B soil (below the Escarpment) are shown in Figure 3. The water table fluctuation follows a similar pattern for both soils. The water table of the Lenswood soil above the Escarpment rises during late June and early July and from this point on remains about 30 cm above the Lenswood B soil below the Escarpment. Both soils exhibit a drawdown in water table during July despite receiving some 57 mm of precipitation. The water table in both soils rise during August and decrease gradually to mid September. The water table in both soils gradually rise from mid September to October.

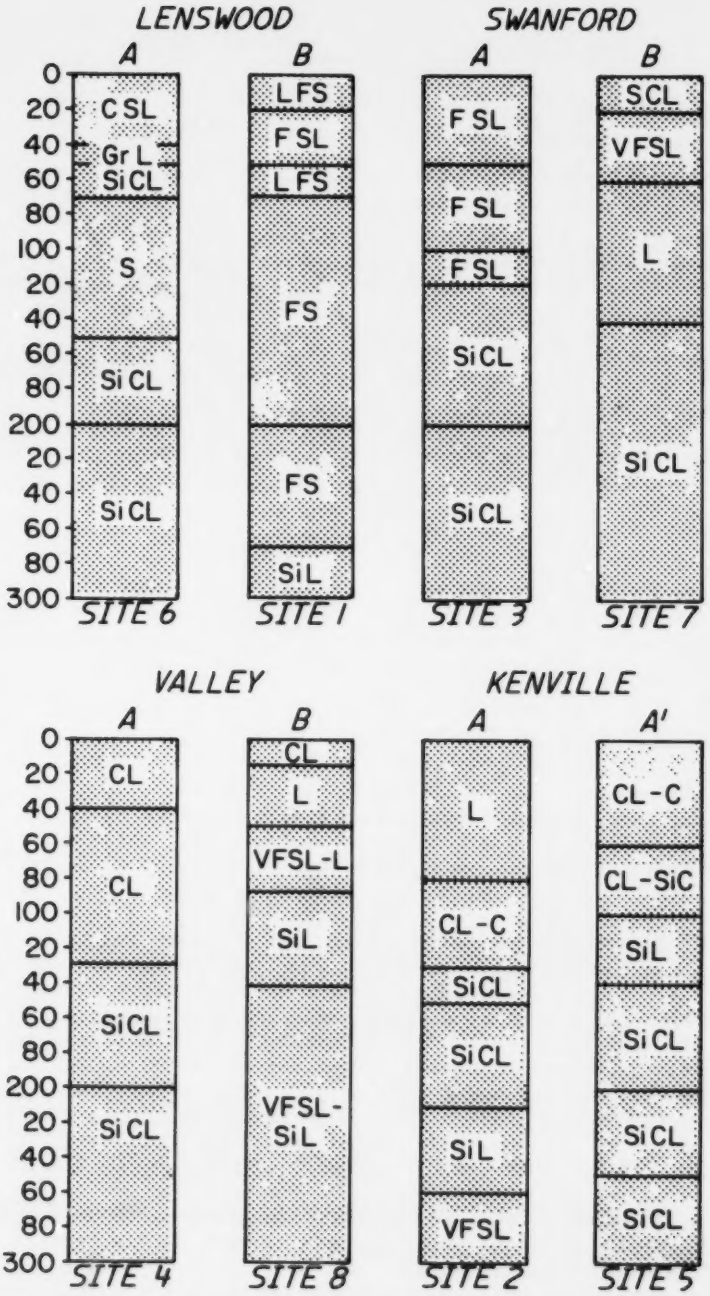


Fig. 2 Drill Logs From Benchmark Soils for Watertable Monitoring (A and A' = Above Kenville Escarpment, B = Below Kenville Escarpment).

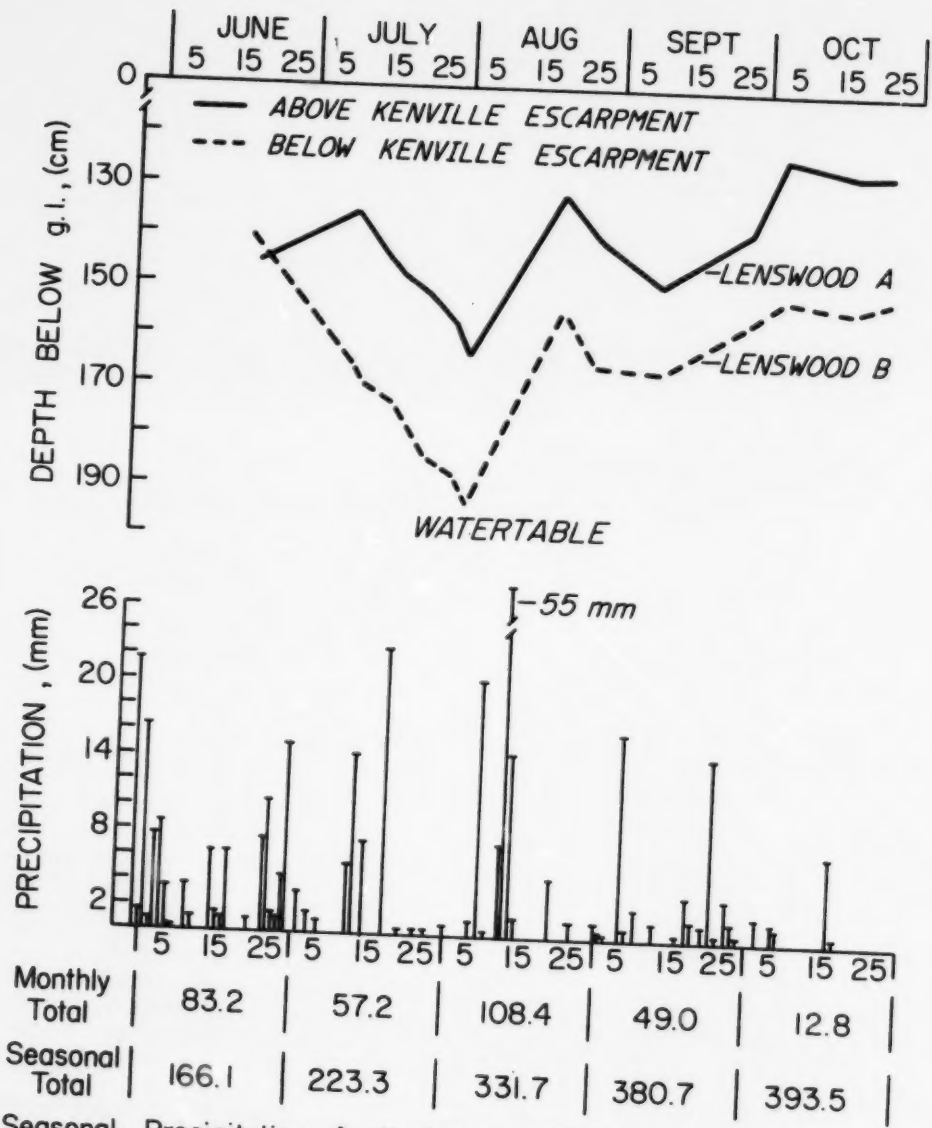


Fig. 3 Watertable - Precipitation Relations on Lenswood Soils During 1985 Growing Season.

Table 1. Characteristics of Benchmark Soils

Soil Name and Location*	Site No	Parent Material	Drainage	Subgroup
Lenswood A	6	Moderately to strongly calcareous sandy to coarse loamy lacustrine sediments	Imperfect	Gleyed Rego Black
B	1			
Swanford A	3	Strongly to very strongly calcareous coarse loamy lacustrine sediments	Imperfect	Gleyed Rego Black
B	7			
Valley A	4	Moderately to strongly calcareous fine loamy lacustrine sediments	Imperfect	Gleyed Rego Black
B	8			
Kenville A	5	Moderately to strongly calcareous fine loamy lacustrine sediments	Well	Orthic Black
A^1	2			

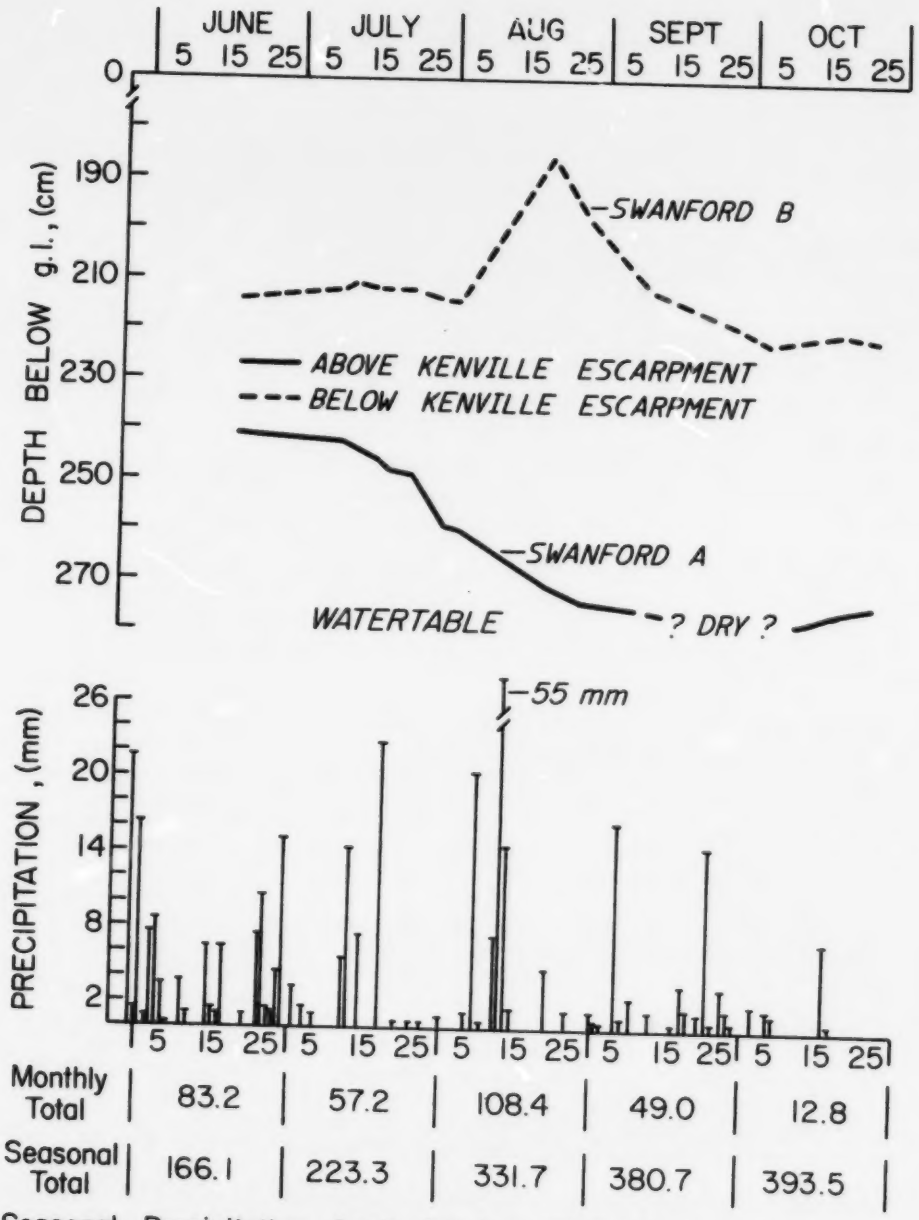
*Location: A and A^1 = above Kenville Escarpment
B = below Kenville Escarpment

The more shallow average depth to water table and early summer increase in water table level on the Lenswood A soil may be attributed to location in close proximity to the Roaring River Delta and the Duck Mountain Escarpment where lateral seepage from the delta may help to maintain the higher groundwater table.

Water table fluctuation observed in the Swanford soils appears to relate more closely to physiographic location (Figure 4). The water table in the Swanford A soil above the Kenville Escarpment is always lower than that observed in the Swanford B soil indicating a greater seasonal drawdown. In contrast, the Swanford B soil has a more shallow depth to water table possibly reflecting generally higher average groundwater levels of the soils below the Kenville Escarpment.

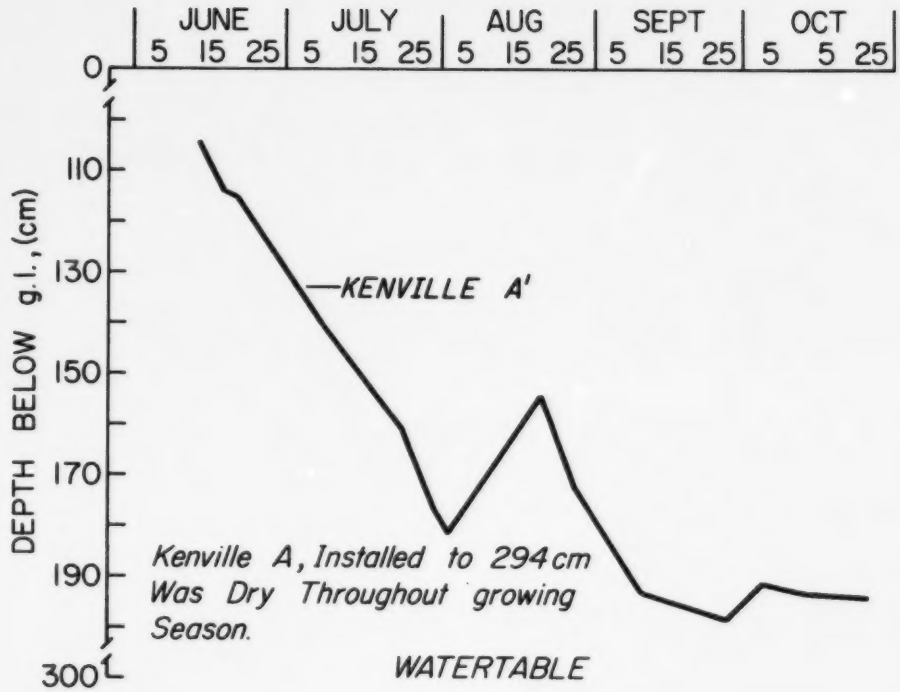
Both Valley soils exhibit a similar pattern of water table fluctuation but with marked difference in degree of fluctuation (Figure 5). The depth to water table observed for each soil cannot be related to the regional geographic setting. The water table in the Valley B soil below the Escarpment averages about 80 cm lower than that observed in the Valley A soil above the Escarpment throughout the growing season until about September 15. At this time, the water table in the Valley A soil is observed to gradually rise through the end of October. In contrast, the water table in the Valley B soil below the Escarpment continues to fall below 3 m from September 15 to October 25.

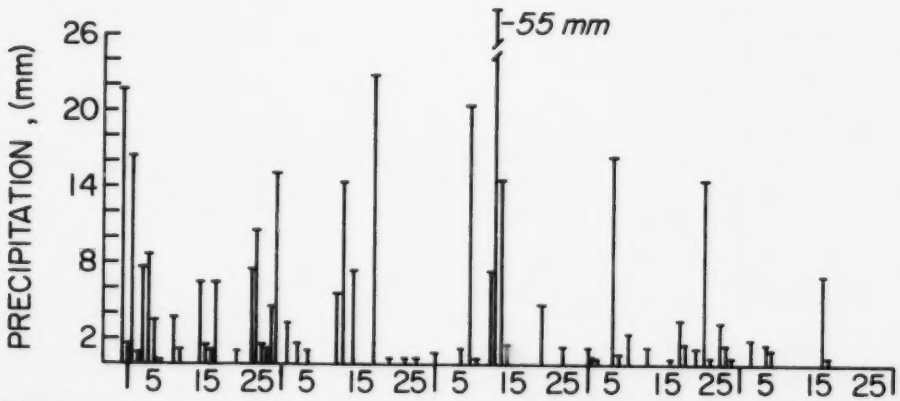
Both Kenville soils occur above the Kenville Escarpment. The Kenville A^1 soil is located within 3 km of the leading edge of the Escarpment and the Kenville A soil some 13 km from the Escarpment edge. The Kenville A soil remained dry to 3 m throughout the growing season. The Kenville A^1 soil closest to the Escarpment edge exhibited water table fluctuation as shown in Figure 6. The water table characteristics in the Kenville



Seasonal Precipitation, April - October, 1985, Swan River

Fig. 4 Watertable - Precipitation Relations on Swanford Soils During 1985 Growing Season.

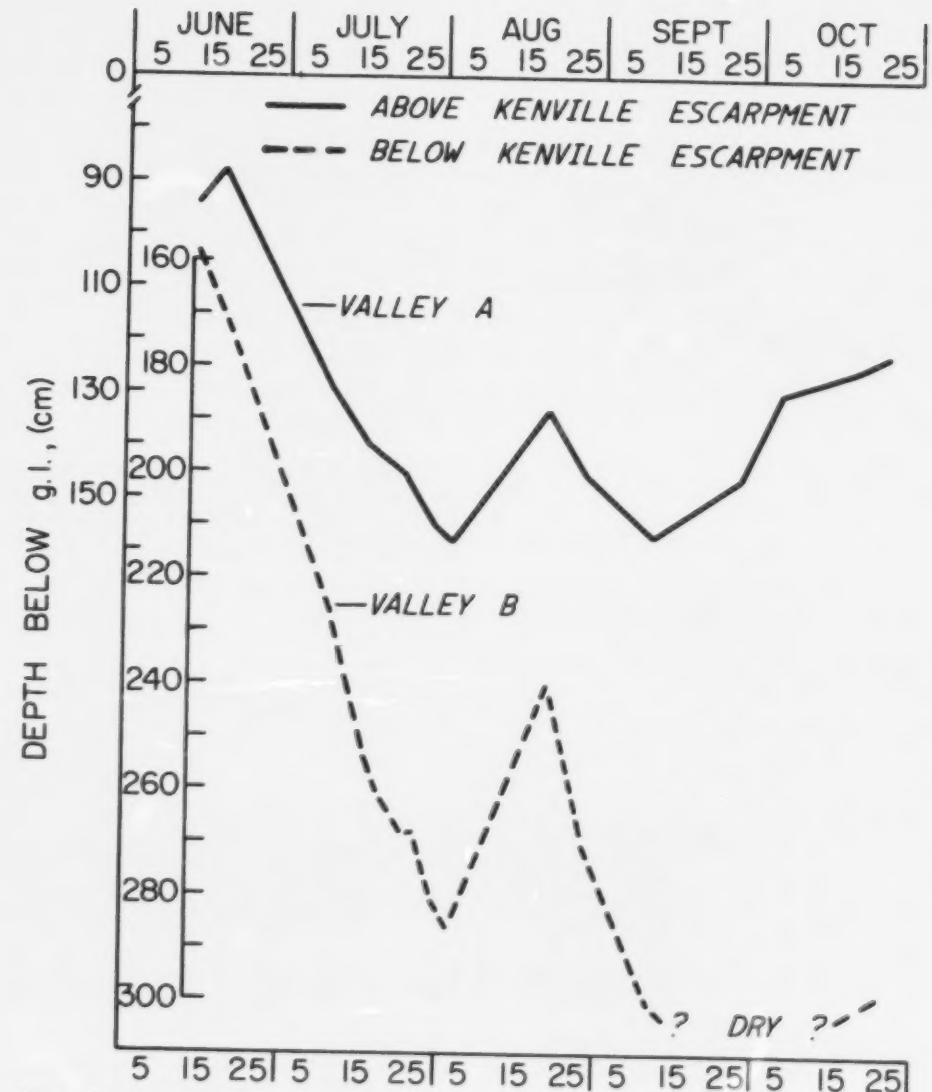




Monthly Total	83.2	57.2	108.4	49.0	12.8
Seasonal Total	166.1	223.3	331.7	380.7	393.5

Seasonal Precipitation, April - October, 1985, Swan River

Fig. 6 Watertable - Precipitation Relations on Kenville Soils During 1985 Growing Season.



Monthly Total (mm)	83.2	57.2	108.4	49.0	12.8
Seasonal Total (mm)	166.1	223.3	331.7	380.7	393.5

Seasonal Precipitation, April - October, 1985, Swan River

Fig. 5 Watertable - Precipitation Relations on Valley Soils During 1985 Growing Season.

A^1 soil may be accounted for by lateral seepage through the more porous sandy strata noted between the 1 m to 1.4 m depth. Seepage from this zone may compensate for an accelerated rate of drawdown resulting from close proximity to the edge of the Escarpment.

The water table characteristics observed in all soils result from the interaction of factors such as stratigraphy, physiographic setting, local hydrologic setting and potential evapotranspiration. The magnitude of groundwater fluctuation is seen to differ even between soils of the same series. Local stratigraphy and hydrologic setting of the soils studied appear to have a greater influence on groundwater fluctuation than does the regional influence of location above or below the Kenville Escarpment. The Lenswood B and Valley B soils have lower average water tables than expected for soils in the generally more poorly drained area below the Escarpment. The extensive network of agricultural drainage associated with the soils below the escarpment may have contributed to a lowering of the regional water tables in this area. Similarily, the Lenswood A and Valley A soils have water tables closer to the surface than might be expected from their location in the generally more freely drained terrain above the Escarpment. Greatest differences in water table fluctuation are noted between the well drained Kenville A soil and the imperfectly drained Valley A soil. A distance of 0.8 km separates these two soils.

Soil Water Regime Classification

The Soil water regime classification proposed for trial use by the Expert Committee on Soil Survey deals with soil characteristics such as hydraulic conductivity and zones of reduced and increased permeability. Kinds of seepage and characteristic of the saturated soil zone are described when present (Eilers, 1982).

Characteristics of Saturated Zone - The proposed classification describes the soil saturated zone in terms of highest and lowest depths to the water table and least and greatest duration of persistence of the saturated zone at particular depths.

The saturated zone in the eight benchmark soils is tentatively classified based on characteristics observed during the 1985 growing season. The classification is incomplete because observations are lacking for the remainder of the year. In addition, a reliable characterization of the soil water regime is dependent on several years data

Application of the proposed criteria serve to highlight differences and similarities in the saturated zone (water table) associated with each soil. Characteristics of the saturated zone summarized for each soil in Table 2 are seen to vary both between and within soil types.

The two Lenswood soils have the same general pattern and range of water table fluctuation, MI (Medium High) to M3 (Medium Low) but differ in the length of time that saturation persists at the least depth (Prolonged at Site 6 and short at Site 1).

The two Swanford soils differ in least depth to saturation zone and the length of time that saturation persists at that depth. The Swanford A soil has a uniform moderately low depth to water table and a medium period of time when the saturated zone persists at the upper end of this range.

Table 2. Characteristics and Classification of Saturated Zone

Soil Name and Location[1]	Site No	Subgroup classification /drainage	Depth to Saturation (average growing season depth, cm)		Duration of least depth, days	Saturation Zone Class[2]		Duration -least depth[3]
			Least	Greatest		Least	Greatest	
Lenswood A	6	Gleyed Rego Black /imperfect	123-150	150-163	107	M1	M3	P
Lenswood B	1	Gleyed Rego Black /imperfect	140-150	150-193	8	M1	M3	S
Swanford A	3	Gleyed Rego Black /imperfect	240-250	250-280	36	L1	L1	M
Swanford B	7	Gleyed Rego Black /imperfect	185-200	200-222	18	M3	L1	S
Valley A	4	Gleyed Rego Black /imperfect	88-150	150-158	88	M1	M3	P
Valley B	8	Gleyed Rego Black /imperfect	160-200	200-300+	17	M3	L2	S
Kenville A[1]	5	Orthic Black /well	108-150	150-193	27	M1	M3	M
Kenville A	2	Orthic Black /well	>300	>300	?	L2	L2	?

1. Location A and A[1] = above Kenville Escarpment
   B = below Kenville Escarpment

2. Saturated Zone - Least and Greatest average growing season depths (cm)

H	High	<100
H1	Very high	0-50
H2	Mod. high	50-100
M	Medium	100-200
M1	Med. high	100-150
M2	Generally low	>150
M3	Med. low	150-200
L	Low	>200
L1	Mod. low	200-300
L2	Very low	>300

3. Duration - least depth

S	Short	2-20 days
M	Medium	20-60 days
P	Prolonged	>60 days

In contrast, the water table in the Swanford B soil fluctuated more widely exhibiting a short period when the zone of saturation occurs at a medium low depth. The water table persists dominantly within moderately low depths.

The Valley soils show differences in characteristics of saturated zone. The Valley A soil has a water table persisting at a medium high least depth for a prolonged time period. The Valley B soil shows only a short time period when the least depth to the water table falls within the medium low depth class.

The saturated zone characteristics of the two Kenville soils also differ from each other. The Kenville A1 soil has a water table persisting in the medium high depth class for a medium time period during the growing season. In contrast, a water table was not detected in the Kenville A soil within a depth of 3 m. The water regime of the Kenville A soil is classified in very low depth class for a prolonged time period during the growing season.

Characteristics of Unsaturated Zone - A complete representation of the yearly pattern of water states for soils includes both saturated soil conditions and the range of unsaturated moisture conditions ranging from wilting point to field capacity. Characterization of the changing pattern of soil water states throughout the year has potential application to a large number of biological and engineering interpretations. However, quantitative evaluation of an average annual water state regime is not currently available as the required data exists for only a few Manitoba soils. Soil properties affecting infiltration and landscape features affecting runoff must be known. The amount and distribution of precipitation and the rate of potential evapotranspiration affect the water state of soil and must be integrated with the effects of a water table if present. Where the appropriate soil properties and meteorological data are known, computer modelling techniques appear to provide the best available method for evaluating these relations and establishing a long-term average picture of the changing moisture states in soil.

An example of a soil moisture diagram has been derived manually from available data from the Swanford B soil, precipitation recorded at Swan River during the 1985 growing season and estimates of average weekly potential evapotranspiration (PE) derived from analyses of climatic data measured at Swan River during 1984. The distribution of soil water states above the water table is estimated under both summerfallow and crop conditions (Figure 7). The following assumptions were made:

- The entire soil profile is at field capacity at the start of the growing season.
- Moisture enters the soil from the top and fills each increment of soil to field capacity before entering the next increment. When the wetting front reaches the capillary zone above the water table, excess moisture is added to the water table causing it to rise.
- Except for excess moisture, removal from the soil is only by evapotranspiration. During early stages of depletion of soil moisture it is assumed that one unit of PE removes one unit of moisture. In later phases, one unit of PE removes less than one unit of moisture; less and less is removed as less and less water remains in the soil moisture profile.

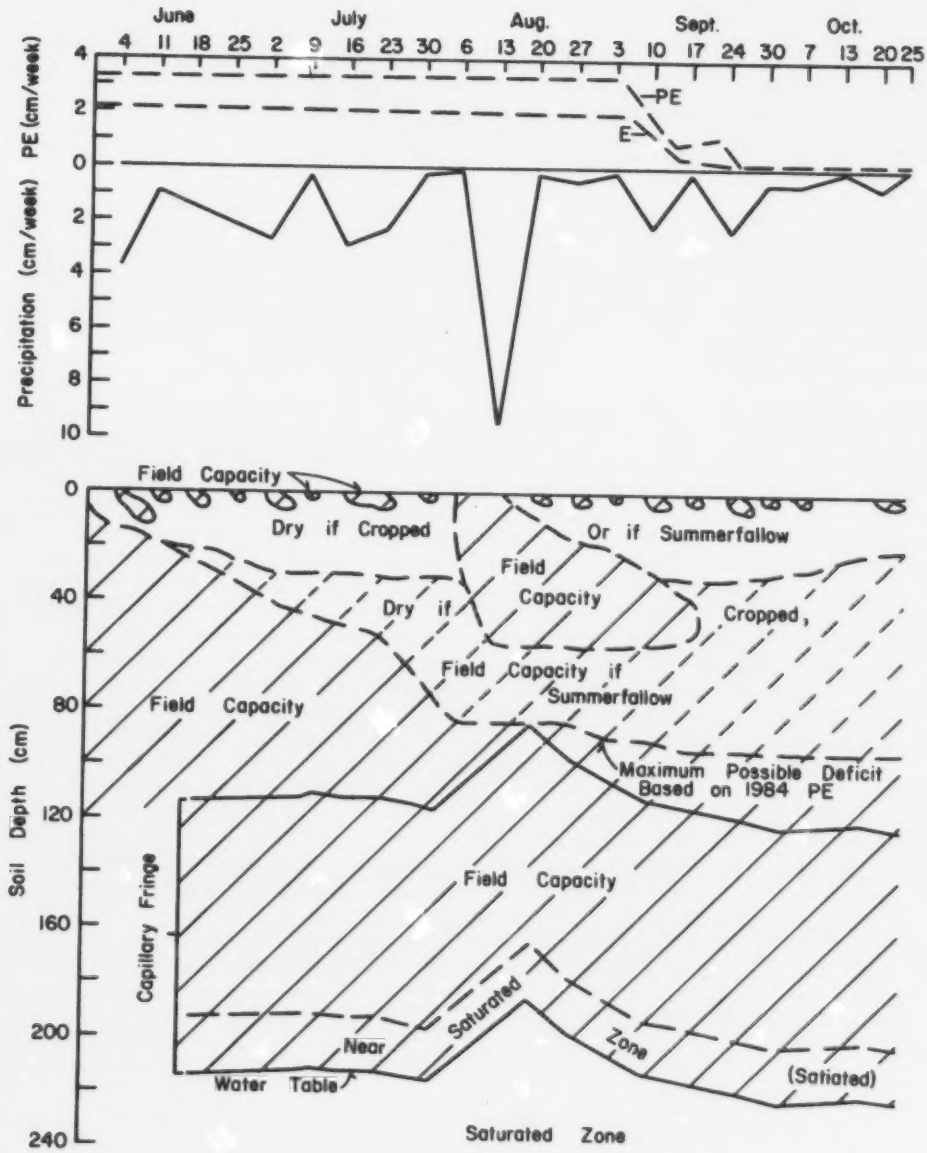


Figure 7. Estimated Distribution of Soil Water States in the Swanford B Soil Under Crop and Summerfallow.

- Monthly precipitation is categorized into "heavy precipitation" which occurs as a principal storm of a particular month and "light precipitation" which occurs in several light rains. The light precipitation is dissipated at the field rate of PE for that month and does not enter the soil except when the precipitation exceeds potential evapotranspiration. Heavy precipitation is assumed to enter the soil instantaneously and is added without loss to any moisture already in the soil.
- Potential evapotranspiration is assumed to be distributed uniformly over all days of the month. The PE available to remove soil moisture is reduced by the PE required to dissipate the light precipitation.
- The moisture profile above the saturated zone (water table) consists of about 25 cm of near-saturated soil and a capillary fringe extending for another 75 cm on Swanford soils developed on uniform coarse loamy sediments. The near-saturated or satiated zone is recognized where free water first appears but water content is slightly less than saturation.

Under crop conditions, water loss from the soil through PE during the growing season will theoretically result in an increasing depth of dry soil eventually reaching the top of the capillary fringe by mid August. If the observed response in water table is attributed entirely to precipitation at this site (ie. no lateral inflow from seepage), then the extensive (approaching 80 cm) dry zone shown for August in Figure 7 could not occur. Rather the thickness of the dry zone should not exceed about 30 cm. A moist soil zone below 30 cm is required to account for the observed water table response. The water content of the 80 cm of soil above the capillary fringe at the time of the August 13 precipitation was such that 60 percent of the rainfall (6.6 cm) was used to bring the 80 cm of soil to field capacity. About 40 percent of the rainfall (4.6 cm) was therefore available to drain to the water table and cause the observed rise. Under the crop scenerio, the soil water deficit above the capillary fringe is such that the August 13 precipitation would not be sufficient to intercept the capillary fringe and cause the water table response.

Water Table Response to Precipitation

The water table fluctuation observed in the benchmark soils is compared to the precipitation received at Swan River during the 1985 growing season (Figure 3,4,5 and 6). The amount and distribution of precipitation recorded at Swan River is assumed to apply uniformly to all soils in the study. An apparent response to this precipitation is noted in portions of the water table curve shown for the Lenswood A and B, Swanford B, Valley A and B and Kenville A[1] soils. There was no observed water table response to incoming precipitation on the Swanford A soil and the well installation in the Kenville A soil was not sufficiently deep to observe if a response occurred.

The occurrence of a water table response to incoming precipitation will depend on soil physical properties, depth to the water table and thickness of capillary rise, moisture content of the soil above the capillary fringe and amount of potential evapotranspiration and precipitation. In southern Manitoba during peak growth periods of the growing season, rainfall accumulation is insufficient to meet the rate

of PE and well and imperfectly drained soils experience seasonal water deficit. On average, there is no water available to move down in the profile and there is an overall tendency for water table levels to fall during June, July and August. In soils having a capillary fringe within the plant root zone, plant growth will utilize additional moisture from this zone and result in lowering the water table.

Following the scenario described in the previous section, water loss through PE should result in an increasing depth of dry soil throughout the course of the growing season. Theoretically, if the dry soil zone is sufficiently thick and the water table sufficiently deep there should be no response to the precipitation levels recorded in 1985. This in fact happened in the Swanford A and Kenville A soils. In order to account for the response observed during August in the water table curve for the other six soils, a large proportion of the soil volume must be near field capacity. The theoretical levels of water deficit accumulated in the average Manitoba growing season would seem to preclude the occurrence of the responses noted, particularly in the Swanford B and Valley B soil where the water table levels were below 2 m prior to the August precipitation.

SUMMARY

It is not possible to draw precise conclusions from the short term observations in this study because the required soil, meteorological and groundwater data is incomplete and because of the many assumptions used to overcome the lack of data.

Interpretation of short-term water table observations is limited because of the variability associated with weather patterns and their influence on groundwater fluctuation. If the short-term data are assumed to provide a "snapshot" of the variation in water table levels within a soil series, then these comparisons indicate that water table measurements should be taken from several representative soils of a particular series rather then from a single soil site.

Water table observations may be difficult to interpret and apply to other soils within a series because of location of the monitoring site. Observations from the Swanford B soil indicate that the fallow soil surrounding the benchmark site may create a groundwater mound and so enable a water table response that would not occur on the same soil if cropped. Similarly, sites located in ditched road allowances, fence rows or shelter belts and farm building sites may not adequately represent water table fluctuation and moisture regime of adjacent cultivated soils.

The proposed soil water regime classification criteria were used to describe the characteristics of the saturated zone in each soil. The criteria were applied to growing season characteristics for one year only but serve to illustrate the range of water table fluctuation that is possible both within and between soil types.

The nature of the water table response to precipitation can best be determined by setting up benchmark sites specifically for this purpose. Water table observations from sites that are not completely characterized and for which the moisture profile is not determined at least 4 times through the growing season have serious limitations for establishing a

reliable relationship between response and incoming precipitation. Ideally, water table depth and precipitation should be recorded continuously. Potential evapotranspiration can be calculated from the closest meteorological station. These data if collected for a minimum of 5 years should be adequate to combine with measured soil physical properties and enable characterization of both the saturated and unsaturated moisture regime of the soil.

The collection of an adquate data base capable of supporting a reliable characterization of variation in annual water states is costly. Adequate manipulation of such data is very time consuming and near impossible by manual techniques. Therefore, attention should be given to the computer generation and manipulation of such data using existing modelling techniques.

References

A.E.S. personal communication, 1985. Atmospheric Environment Service Environment Canada, Winnipeg, Manitoba.

Ehrlich, W.A., L.E. Pratt and F.P. LeClaire, 1962. Report of the Detailed-Reconnaissance Soil Survey of the Swan River Map Sheet Area. Soils Report No. 13, Manitoba Soil Survey, Manitoba Dept. of Agriculture.

Eilers, R.G., 1982. Soil Water Regime Classification, 1982. Proceedings Fourth Annual Meeting, Expert Committee on Soil Survey, Agriculture Canada. pp. 39-51.

Michalyna, W., 1984. Permeability and Capillary Properties of Some Manitoba Soils. Papers presented at the 27th Annual Manitoba Society of Soil Science Meeting, Manitoba Agriculture. pp. 41-45 and pp. 55-71.

Michalyna, W. and P. Haluschak, 1985. Soil Physical Properties of Selected Soils on Tills and Lacustrine Deposits in Manitoba. Papers presented at the 28th Annual Manitoba Society of Soil Science Meeting, Manitoba Agriculture. pp. 155-166.

Nowland J.L., 1981. Soil Water Regime Classification, 1981. Proceedings Third Annual Meeting, Expert Committee on Soil Survey, Agriculture Canada, Ottawa. pp. 64-74.

Onofrei, C. and R. Smith, 1985. A Land Productivity Assessment Procedure Using Simulation Techniques. Technical Report, Dept. of Soil Science, University of Manitoba and Canada-Manitoba Soil Survey.

SCS 1983. Moisture in Soils. Report of Standing Committee II. Proceedings of the National Technical Work-Planning Conference of the Cooperative Soil Survey, Soil Conservation Service, U.S.D.A. Washington, D.C. pp. 101-175.

THE EFFECT OF DICLOFOP-METHYL AND HOEGRASS™ ON ANAEROBIC NITROGEN TRANSFORMATIONS

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ABSTRACT

The effect on anaerobic nitrogen transformations of diclofop-methyl and its commercial formulation, HoeGrass™, was studied in two Almasippi sands. Maximum rates of nitrate reduction ranged from -1.77 μg NO_3-N g^{-1} soil, in the soil with a low organic content, to -22.17 μg g^{-1} in the high organic soil. Nitrite reduction rates ranged from approximately -0.98 to 3.2 μg NO_2-N g^{-1}. Generally the herbicides affected nitrate reduction rates less in the high organic soil and nitrite reduction rates less in the low organic soil. The effects in both soils were more pronounced at the 100 μg a.i. g^{-1} soil and greatest for HoeGrass™.

INTRODUCTION

Anaerobic nitrogen transformations are an important avenue for soil nitrate losses. The nitrate is reduced to nitrite then to nitric oxide, nitrous oxide and dinitrogen. The gaseous forms escape the soil, resulting in a loss of soil nitrogen. This process is generally termed denitrification. Nitrogen losses through denitrification have been estimated to range from 0 to 70%, although it appears that in most situations denitrification probably accounts for a 15 to 30% loss of applied fertilizer nitrogen.

Since herbicides are commonly applied to or end up in agricultural soils, it is possible for a herbicide to exert an affect on the denitrification process. A study was initiated to determine if diclofop-methyl had any affects on the initial processes of denitrification, i.e., nitrate and nitrite reduction. The commercial formulation of a pesticide can behave differently than the technical product, therefore this study also examined the commercial emulsifiable concentrate HoeGrass™.

MATERIALS AND METHODS

Bulk soil samples of the top 20 cm of two Almasippi soils were used in the study. The soils were obtained from agricultural areas in southern Manitoba which had no recent history of pesticide applications. The soils were air dried, sieved through a 2 mm sieve, and stored in 1.7-L glass jars. The physical and chemical characteristics of the two soils were determined by the Manitoba

Provincial Soil Testing (MPST) Laboratory (Table 1). The pH ranged from 7.5-7.9. The salinity was 0.02 S m^{-1}. Nitrate and phosphate were extracted with 0.5 mol L^{-1} sodium bicarbonate, pH 8.5. Nitrate was analyzed by the hydrazine sulfate method employing a Technicon Auto Analyzer. The potassium concentrations represent potassium extracted with 1 mol L^{-1} ammonium acetate.

Table 1. Physical and chemical characteristics of soils

Soil	% Sand	% Silt	% Clay	% OM	Nitrate ($\mu g\ g^{-1}$)	Phosphate ($\mu g\ g^{-1}$)	Potassium ($\mu g\ g^{-1}$)
P2	44	37	19	2.5	28.2	4.0	295
P3	89	5	6	2.3	111.3	2.8	30

Twenty grams of air-dried soil was added to a 250 mL screw top Erlenmyer flask. Diclofop-methyl (97.9%, Hoechst) or HoeGrass™ (190 g L^{-1}, Manitoba Cooperatives Ltd.) was added to the soil to a final concentration of 10 or 100 µg a.i. diclofop-methyl g^{-1} air-dried soil. All concentrations stated are based on air-dried soil. Three samples were run simultaneously: a control sample (no pesticide), a 10 µg g^{-1}, and a 100 µg g^{-1}. At least 4 replications were obtained for each sample. Nitrate was added to soil P2 to bring the NO_3 concentration up to approximately 100 µg NO_3-N g^{-1}. A 1.5 mL stock microbial culture was added to the flask. For the glucose ammended soils, the final concentration was 200 µg glucose g^{-1}. If necessary, the soil was then brought up to a final water content of 40 mL with distilled water. The sample was shaken for 15 minutes and a 0.2 mL of the soil solution was removed for nitrate and nitrite analysis. The 0.2 mL sample was filtered with a 0.45 m filter and 1 µL of the filtrate was injected into the HPLC for nitrate and nitrite analysis.

The flask was sealed with a holed screw cap backed with a teflon-silicon liner. The flasks were then vacuum evacuated for 10 min and flushed with prepurified helium (99.996%). This operation was performed three times. Since nitrous oxide levels were also monitored (results not shown) by the acetylene inhibition technique (Balderston et al. 1976, Yoshinari and Knowles 1976), 20 mL of purified C_2H_2 (99.6%) was added to each flask with a gas-tight syringe (Hamilton). The flask was then measured for residual oxygen with a helium ionization detector (HID). Generally oxygen levels were found to be less than 1% of ambient. The flasks were then incubated shaking in a 24°C water bath. Periodically 0.4 ml of the soil solution was removed with a 10 mL syringe for nitrate and nitrite analysis.

Nitrate and nitrite analysis was performed by high performance liquid chromatography (HPLC) analysis with UV detection at 214 nm (Kuchnicki et al. 1985). A 4 mm I.D. x 250 mm 10 m LiChrosorb RP-18

column (Merck) was operated at ambient temperature (ca. 24°C).

RESULTS AND DISCUSSIONS

Soil P3:

The 10 μg g^{-1} treatment of diclofop-methyl decreased significantly the time of nitrate reduction (Figure 1a). No effect was noticeable at the 100 μg g^{-1} treatment. In contrast, nitrite reduction was inhibited slightly by the 100 μg g^{-1} treatment. The 10 μg g^{-1} HoeGrass™ treatment was less effective at reducing the time of nitrate reduction (Figure 1b). Nitrite reduction rates were again not affected at the 10 μg g^{-1} HoeGrass™ level, whereas the 100 μg g^{-1} treatments increased nitrate reduction times. Except for the 100 μg g^{-1} HoeGrass™ treatment, the maximum concentration of nitrite was approximately 45 μg NO_2-N g^{-1}.

Analysis of the linear portions of the curves by linear regression revealed the maximum rates of nitrate and nitrite reduction attainable under the experimental conditions (Table 2).

Table 2. Maximum rates of nitrate (μg NO_3-N g^{-1} h^{-1}) and nitrite (μg NO_2-N g^{-1} h^{-1}) reduction.

	NITRATE			NITRITE		
	Control	10 μg g^{-1}	100 μg g^{-1}	Control	10 μg g^{-1}	100 μg g^{-1}
P3						
Diclofop	-2.60	-3.12	-2.31	-1.46	-1.44	-1.19
HoeGrass™	-2.60	-2.45	-1.77	-1.46	-1.49	-0.98
D + Glc	-16.52	-15.98	-16.00	-2.50	-2.20	-1.64
H + GlC	-16.52	-17.76	-13.85	-2.50	-2.40	-1.25
P2						
Diclofop	-7.37	-8.88	-7.37	-2.77	-2.82	-1.43
HoeGrass™	-7.37	-7.64	-7.83	-2.77	-2.47	-1.20
D + Glc	-20.10	-18.96	-17.92	-3.28	-2.65	-2.55
H + Glc	-20.10	-22.17	-22.03	-3.28	-2.71	-1.94

The values given in Table 2 are the averages of 3 to 6 trials. The 10 μg g^{-1} diclofop-methyl treatment increased the rate of nitrate reduction to -3.12 μg NO_3-N g^{-1} h^{-1}. As the concentration of HoeGrass™ increased, the rate of nitrate reduction slightly decreased. Further statistical analysis will determine if these differences are significant. Nitrite reduction rates were not affected by the 10 μg g^{-1} treatment but decreased significantly at the 100 μg g^{-1} treatment.

The regression lines were extrapolated to the abcissa and the intersection with the abcissa was regarded as the time of disappearance of nitrate or nitrite (Table 3). At 10 µg g^{-1},

Table 3: Time required (h) for complete disappearance of nitrate and nitrite.

	NITRATE			NITRITE		
	Control	10 µg g^{-1}	100 µg g^{-1}	Control	10 µg g^{-1}	100 µg g^{-1}
P3						
Diclofop	62.5	52.5	62.5	87.0	82.0	115.0
HoeGrass™	63.0	60.0	83.0	87.0	87.0	136.0
D + Glc	22.5	22.5	22.5	52.8	52.8	60.3
H + Glc	22.6	22.6	25.2	52.5	56.0	86.0
P2						
Diclofop	26.5	24.3	28.2	57.0	50.0	64.0
HoeGrass™	26.7	28.2	27.5	57.5	56.0	84.0
D + Glc	15.9	16.5	17.3	35.5	36.2	39.7
H + Glc	15.5	15.2	16.5	36.5	37.0	44.0

dicolfop-methy reduced the time of nitrate disappearance by 10 h. Even though 10 µg g^{-1} HoeGrass™ slightly reduced the rate of nitrate reduction, nitrate disappeared 3 h earlier from the system. The 100 µg g^{-1} treatment of HoeGrass™ increased the time of nitrate disappearance by 20 h.

Nitrite disappeared 5 h faster with the 10 µg g^{-1} treatment of diclofop-methyl, whereas the 100 µg g^{-1} treatment of diclofop-methyl and HoeGrass™ increased disappearance times by 28 and 49 h respectively.

In soil P3, although nitrate disappearance is 10 h faster with 10 µg g^{-1} diclofop-methyl, nitrite disappearance is only 5 h faster, indicating that nitrite reduction is still affected at the 10 µg g^{-1} level. A similar pattern, of a reduced time of nitrate disappearance and less of an effect on nitrite reduction time, is seen for the 10 µg g^{-1} HoeGrass™ treatment.

As expected, the addition of glucose, an energy source, increased both nitrate and nitrite reduction (Figure 2.) More significant, maximum nitrite levels were about 80 µg NO_2-N g^{-1}, almost twice that obtained without glucose (Figure 1). Nitrate reduction also appeared to be biphasic, with an initial rate of approximately -9 µg NO_3-N g^{-1} h^{-1}. Considering the cosmopolitan nature of the microbial culture, a microbial sucsession of different nitrate reducers may be occurring. Diclofop-methyl (Figure 2a) had less of an effect on nitrate and nitrite reduction than in the glucose deficient soils. HoeGrass™ (Figure 2b) had a greater effect on nitrate and nitrite reduction, especially at the 100 µg g^{-1} level.

For the control samples, nitrate reduction rates (Table 2) increased 535% with glucose amendment. Diclofop-methyl had little effect at any level, whereas 100 μg g^{-1} HoeGrass™ decreased nitrate reduction significantly. In both soils, 100 μg g^{-1} HoeGrass™ decreased nitrate reduction approximately 3 to 5 times more than the 100 μg g^{-1} diclofop-methyl treatments. A maximum decrease of 27.8% in nitrate reduction occurred in the non-glucose amended soil at the 100 μg g^{-1} HoeGrass™ level.

For both diclofop-methyl and HoeGrass™, nitrite reduction decreased with increasing herbicide concentrations. However, the glucose amended soils had a greater decrease in nitrite reduction than the non-glucose soils. The highest decrease (50%) occurred at the 100 μg g^{-1} HoeGrass™ level in the glucose amended soil. Therefore, glucose decreased the effectiveness of 100 μg g^{-1} of diclofop-methyl or HoeGrass™ in reducing nitrate reduction rates, but increased the effectiveness at reducing nitrite reduction rates.

Glucose produces a 64% decrease in the time of disappearance of nitrate in the control (Table 3). No effect is seen in disappearance times for the diclofop-methyl treatments, whereas 100 μg g^{-1} HoeGrass™ increased the disappearance time by 2.6 h. Diclofop-methyl at 100 μg g^{-1} increased nitrite disappearance by 7.5 h. Increasing HoeGrass™ concentrations resulted in increased nitrite disappearance times. The disappearance times at 100 μg g^{-1} are decreased 37-47% by the amendement of the soil with glucose.

The decrease, in nitrate reduction rates and times, is a consequence of the increase in microbial metabolic rates with an increase in the energy source, glucose. The decrease in nitrite reduction rates with an increase in the energy level, may indicate 1) the predominante microorganism(s) responsible for nitrite reduction differ(s) in the two soils and/or 2) the microorganism(s) responsible for nitrite reduction differ(s) from those responsible for nitrate reduction and is (are) selected for by the use of glucose.

Soil P2

In this nutritionally richer soil, nitrate and nitrite reduction curves were similar to the P3 + glucose amended soil (Figure 3 vs Figure 2). However, the 100 μg g^{-1} treatments of both diclofop-methyl and HoeGrass™ resulted in a substantial lower level of nitrite recovered; approximately 45-50 μg NO_2-N g^{-1} vs 75 for the control. Nitrite reduction was enhanced for both diclofop-methyl and HoeGrass™ at 10 μg g^{-1}.

Nitrate reduction rates (Table 2) were 183% greater than soil P3 without glucose and 55% less than the P3+glucose soil. Diclofop-methyl at 10 μg g^{-1} increased nitrate reduction 20%, an increase similarly experienced in soil P3. HoeGrass™ treatments increased nitrate reduction with increasing concentrations, although the 6% increase may not be statistically significant. The 100 μg g^{-1} treatments reduced nitrite reduction rates (Table 2); a maximum decrease of 56.7% was observed with the HoeGrass™ treatment.

The disappearance times for nitrate (Table 3) varied from 2 h less than the control for the 10 g g^{-1} diclofop-methyl treatment, to 2 h more for the 10 µg g^{-1} HoeGrass™ treatment. In contrast with the P3 soil, the 100 µg g^{-1} HoeGrass™ treatment did not significantly affect the nitrate disapperance time. Nitrite disappearance times were affected more, with the largest increases in time noted for the 100 µg g^{-1} treatments. A comparison with soil P3 shows the same pattern of a lowered disappearance time with the 10 g g^{-1} diclofop-methyl treatment, no difference with the 10 µg g^{-1} HoeGrass™ treatment, and a substantial increase with the 100 µg g^{-1} treatments.

With the addition of glucose to soil P2, the maximum nitrite level for all the treatments was approximately 55 µg NO_2-N g^{-1} (Figure 4). In this soil the addition of glucose appears to prevent elevated nitrite levels. The 100 µg g^{-2} treatment caused a shift in the nitrite curve such that the time at which the maximum occurred was retarded by approximately 1 to 5 h.

Nitrate and nitrite reduction rates increased 62.8% and 18.4% respectively (Table 2). Nitrate reduction rates decreased with increasing diclofop-methyl concentrations. The increase in nitrate reduction for increasing HoeGrass™ treatments was also observed in the P2 soils without glucose. Nitrite reduction rates decreased with increasing herbicide concentrations, however, the decreases at the 100 µg g^{-1} level were less than that for the P2 soils without glucose. A maximum decrease of 40.9% was experienced with the 100 µg g^{-1} HoeGrass™ treatment. In contrast to soil P3, the addition of glucose resulted in less inhibition of nitrite reduction rates.

Nitrate disappearance times (Table 3) increased slightly for the 100 µg g^{-1} treatments. Nitrite disappearance times also increased slightly, with a maximum increase of 7.5 h with the 100 µg g^{-1} HoeGrass™ treatment. The addition of glucose resulted in less differences between the treatments. These differences were also considerably less than experienced with soil P3 amended with glucose.

SUMMARY

In all situations, nitrate reduction varied considerably less than nitrite reduction. The greatest differences in nitrate reduction between treatments varied from +6 to -27.8%; the differences in nitrite reduction ranged from -18.5 to -56.7%. Generally the 100 µg g^{-1} HoeGrass™ treatments produced the greatest decrease in nitrate and nitrite reduction rates. It was not uncommon for the 10 µg g^{-1} diclofop-methyl treatments to increase nitrate reduction rates and, in some cases, the nitrite rate. Generally nitrite reduction rates decreased with increasing herbicide concentration.

The addition of a carbon source, glucose, substantially increased the rates of nitrate and nitrite reduction. As the rate of nitrate reduction increased, there was generally less of a difference between the control and 100 µg g^{-1} treatments.

LITERATURE CITED

Balderston, W.L., Sherr, B., and Payne, W.J. 1976. Blockage by acetylene of nitrous oxide reduction by Pseudomonas perfectomarinus. Appl. Envir. Microbial. 31:504-508.

Kuchnicki, T.C., Sarna, L.P., and Webster, G.R.B. 1985. Determination of nitrate, nitrite, and phosphate at 214 nm by reverse phase HPLC. J. Liq. Chromatogr. 8:1593-1609.

Yoshinari, T. and Knowles, T. 1976. Acetylene inhibition of nitrous oxide reduction by denitrifying bacteria. Biochem. biophys. Res. Commun. 69:705-710.

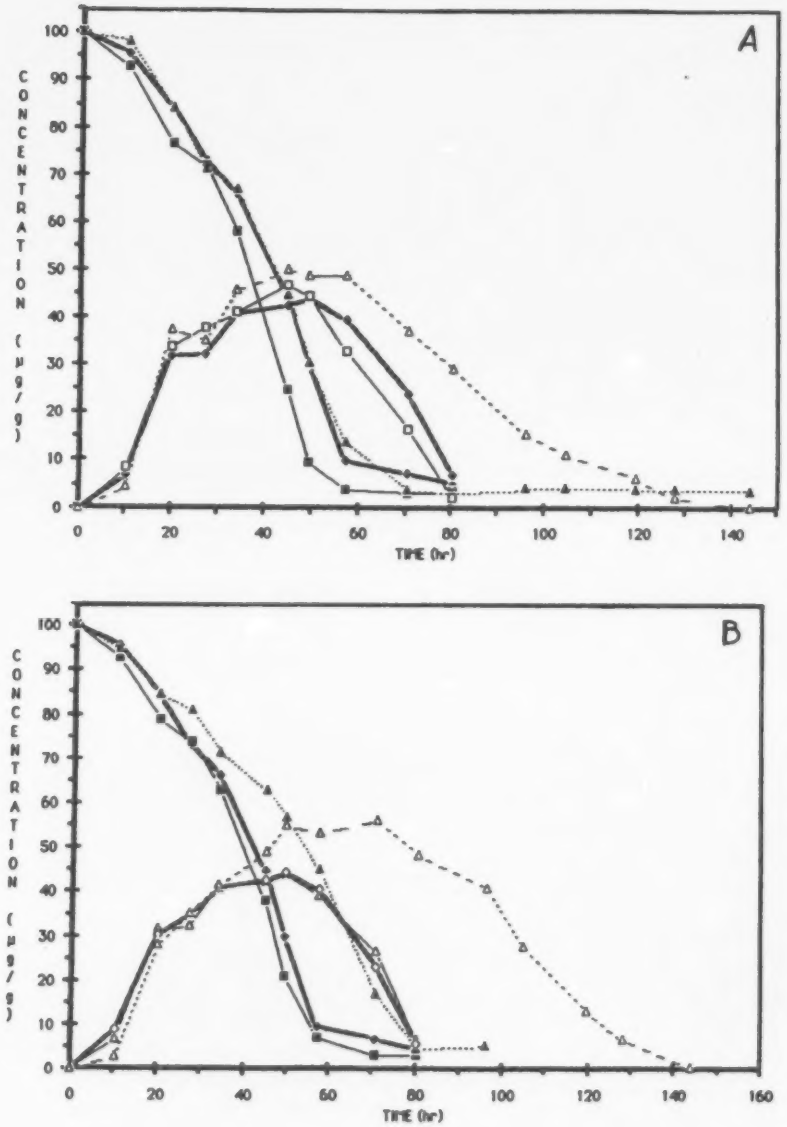

Figure 1. The effect of a) diclofop-methyl and b) HoeGrass™ on nitrate and nitrite reduction in soil P3. Nitrate: Control (◆—◆), 10 µg g^{-1} (■—■), 100 µg g^{-1} (▲--▲). Nitrite: Control (◇—◇), 10 µg g^{-1} (□—□), 100 µg g^{-1} (△--△).

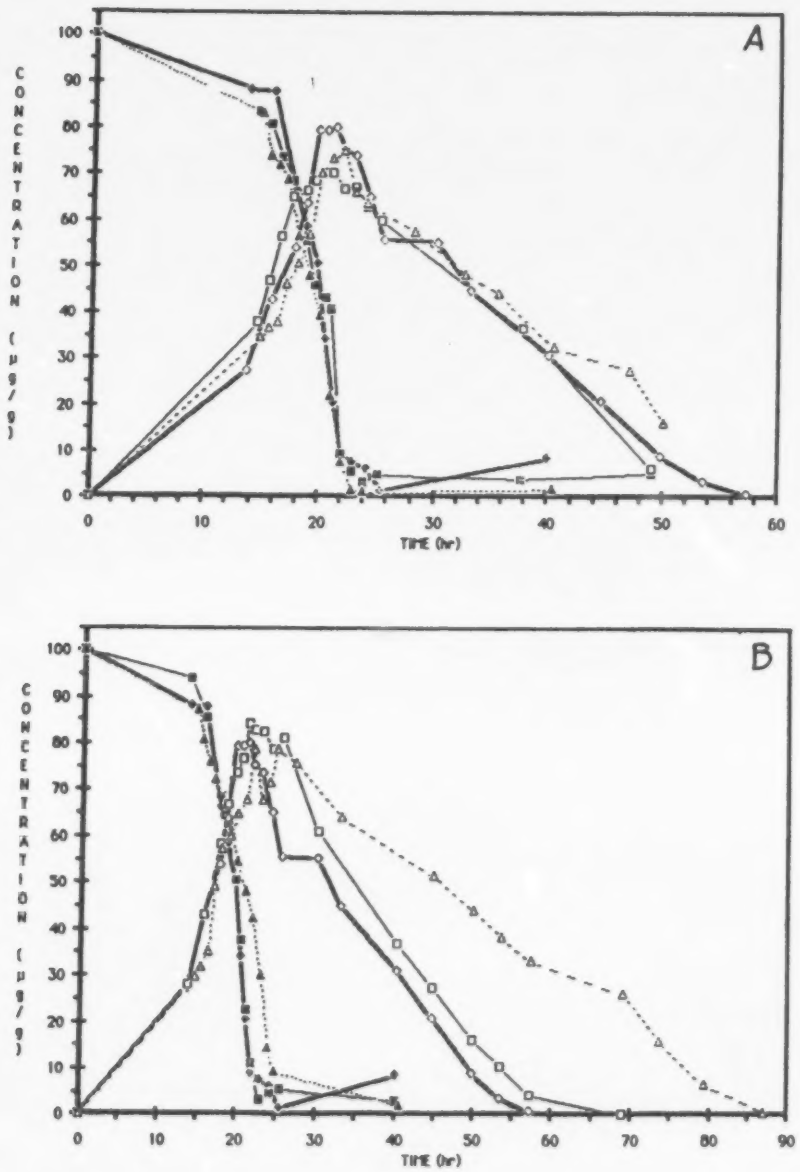

Figure 2. The effect of a) diclofop-methyl and b) HoeGrass™ on nitrate and nitrite reduction in soil P3 amended with 200 µg g^{-1} glucose. Line legend identical to Figure 1.

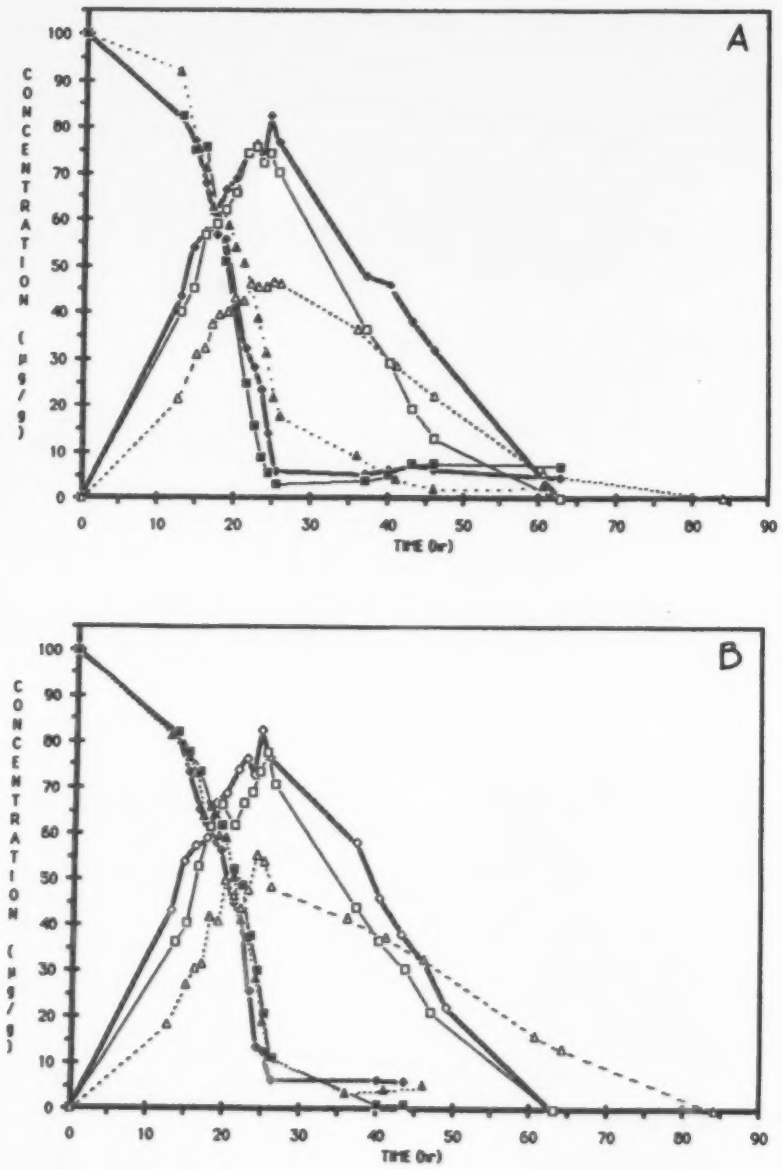

Figure 3. The effect of a) diclofop-methyl and b) HoeGrass™ on nitrate and nitrite reduction in soil P2. Line legend identical to Figure 1.

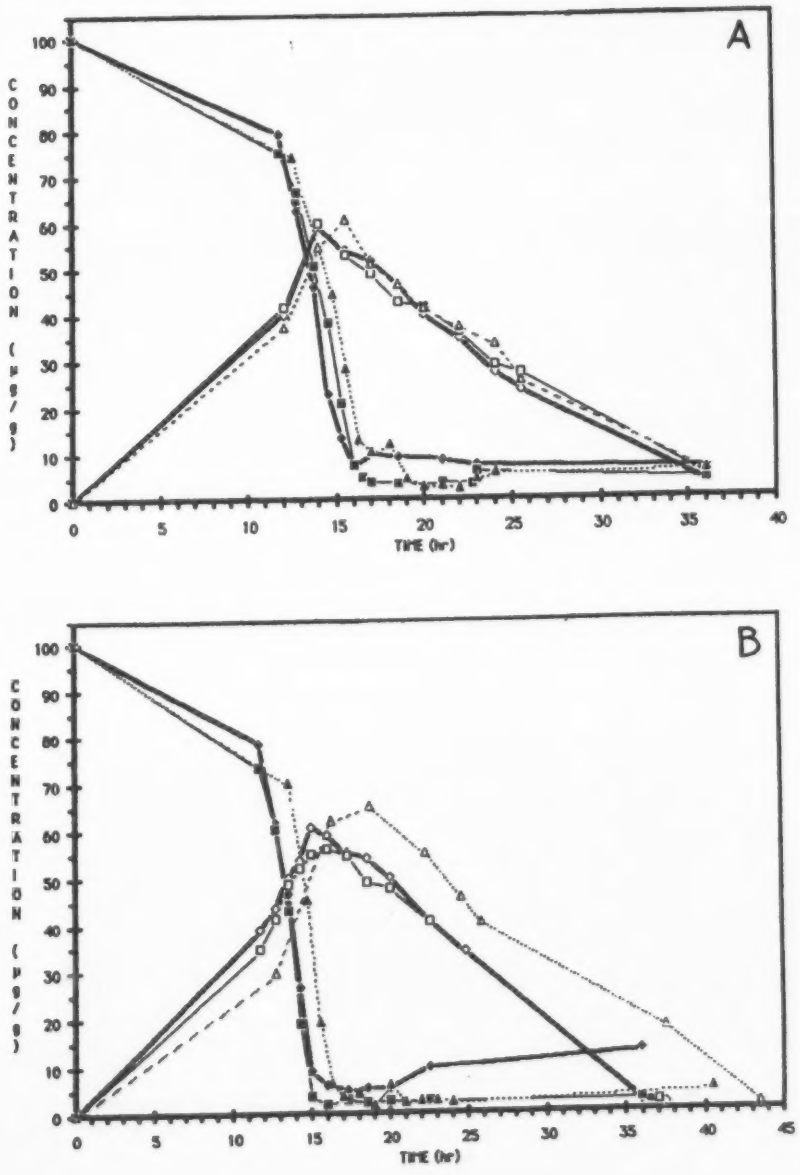

Figure 4. The effect of a) diclofop-methyl and b) HoeGrass^{TM} on nitrate and nitrite reduction in soil P2 amended with 200 µg g^{-1} glucose. Line legend identical to Figure 1.

NITROGEN REQUIREMENTS OF SEMI-DWARF VERSUS CONVENTIONAL VARIETIES OF WHEAT UNDER MANITOBA CONDITIONS

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A three-year experiment to determine the N fertilizer responsiveness and yield potential of traditional and semi-dwarf spring wheat cultivars under Manitoba conditions was initiated in 1985.

Materials and Methods

The 3 sites used in 1985 represent a range of soil-climatic conditions typical of the major wheat growing areas of Manitoba. The site and soils information is presented in Table 1. Note that initial N fertility was low at all 3 sites.

Table 1. Site and soils information for ERDA wheat project, nitrogen response experiment (soils sampled in April, 1985)

Location	Miami (NW 14-5-6 W1)	Minnedosa (NE 23-14-18 W1)	Souris (NW 18-7-21 W1)
Previous crop	corn	barley	wheat
Date sown	May 22	May 24	May 17
Date harvested	October 19	October 22	Sept. 13
Soil type and Texture	V.F. Sandy Loam	Newdale Clay	Souris Silty Clay Loam
pH(1:1 soil:water)	7.7	7.9	7.4
Salinity(mS/mm)	0.2	0.4	0.2
Nitrate-N (kg N/ha to 60cm)	26 (L)*	22 (L-)	23 (L)
$NaHCO_3$-P (kg P/ha to 15cm)	39 (H)	19 (L)	23 (L)
Exch-K (kg K/ha to 15cm)	398 (VH-)	732 (VH+)	481 (VH+)
Sulphate-S (kg S/ha to 60cm)	72 (VH+)	63 (VH)	18 (L)
Fertilizer applied (kg/ha) 11-52-0 banded with seed	40	70	70
Sulfur broadcast as gypsum	0	0	12

* Manitoba Provincial Soil Test Lab. fertility ratings: L = low, M = medium, H = high, VH = very high.

At each site, the experiment was conducted as a split-plot design with 4 replicates. Main plot treatments were 6 cultivars(cv) of wheat (the U.S. semi-dwarf cv's Solar, Marshall and Len, the Canadian semi-dwarf cv HY320, the hard red spring cv Katepwa and the utility cv Glenlea). Subplot treatments were 7 rates of N fertilizer from 0 to 240 kg N/ha in 40 kg N/ha increments applied as urea (46-0-0) in a band between rows. Subplots were nine 13-m long rows at 20 cm spacings. Seeding and fertilizer application were done simultaneously with a fertilizer placement plot seeder; an exception being sulfur at Souris which was broadcast as gypsum and harrow incorported before seeding.

The data collected from each plot included: above-ground dry matter accumulation at the early post-anthesis stage of Katepwa, above ground dry matter accumulation at maturity, grain yield and harvest index. Soil samples from the 0 and 120 kg N/ha treatments were taken at mid-season to determine moisture useage and available N. Daily precipitation was recorded at each site.

Results

Grain yields and the patterns of N fertilizer grain yield response for each of the cultivars were similar for the Minnedosa and Souris sites (Tables 2 and 3).

Table 2. Grain yield response of spring wheat cultivars to nitrogen fertilizer in 1985 at Minnedosa, Manitoba

CULTIVAR	KATEPWA	GLENLEA	HY320	LEN	MARSHALL	SOLAR
N APPLIED kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha
0	1419	1601	1740	1466	1374	1781
40	2420	2226	2588	2293	2334	2358
80	2966	2777	3710	2804	3292	3428
120	3244	3094	4619	3036	3822	3888
160	3055	3134	4760	3360	4026	3875
200	3368	3004	4770	3219	4106	3988
240	3181	3102	4804	3167	4243	3894

Std. error = 73 kg/ha

Table 3. Grain yield response of spring wheat cultivars to nitrogen fertilizer in 1985 at Souris, Manitoba

CULTIVAR	KATEPWA	GLENLEA	HY320	LEN	MARSHALL	SOLAR
N APPLIED kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha
0	1375	1636	1628	1227	1270	1567
40	1955	2081	2658	2166	2179	2342
80	2453	2915	3812	2243	3069	3212
120	2651	3108	4190	2718	3456	3567
160	2314	2801	4485	2056	3633	3277
200	2841	3011	4437	2287	3438	3885
240	2033	2773	4552	2189	3520	3637

Std. error = 83 kg/ha

The N fertilizer grain yield responses at Souris and Minnedosa follow classic textbook patterns with low initial yields reflecting the initial N fertility, near linear responses to increasing N application to a maximum level and constant yields at higher N rates. With the exception of Katepwa at Souris, the highest rate of N fertilization, 240 kg/ha, did not depress yields due to overfertilization (lodging was not a problem at either Souris or Minnedosa). Cultivar yield levels and yield responses to applied N at Souris and Minnedosa fell into 3 categories:

1) HY320 had a high check yield and the highest grain yields at N levels $\geq$ 40 kg/ha. HY320 showed the greatest grain yield responses to N fertilizer application,
2) Marshall and Solar had similar grain yields and grain yield responses to applied N at rates > 40 kg N/ha. The check yields of Solar were higher than those of Marshall. At N rates > 40 kg/ha Marshall and Solar had grain yields and grain yield responses less than those of HY320 but greater than those of Katepwa, Glenlea and Len,
3) Katepwa, Glenlea and Len had similar grain yields and grain yield responses to N application. At N rates > 40 kg/ha Katepwa, Glenlea and Len showed consistently lower grain yields and grain yield responses to N application than HY320, Marshall and Solar.

At the Miami site, although available N at seeding was similar to that of the other 2 sites, the check yield levels were higher (Table 4). However, yield increases due to applied N were lower than at either Souris or Minnedosa.

Table 4. Grain yield response of spring wheat cultivars to nitrogen fertilizer in 1985 at Miami, Manitoba

CULTIVAR	KATEPWA	GLENLEA	HY320	LEN	MARSHALL	SOLAR
N APPLIED kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha	YIELD kg/ha
0	1926	1882	2874	2122	2360	1980
40	2026	2411	3022	2413	2940	2734
80	3045	2729	3487	2483	3427	2801
120	2943	3139	3262	2592	3281	3055
160	3171	3071	3681	2624	3467	3354
200	3183	2988	3270	2403	3640	3132
240	2840	3032	3395	2307	3364	3271

Std. error = 45 kg/ha

At N levels > 40 kg/ha HY320 and Marshall had the highest grain yields and Len the lowest grain yields. Katepwa, Glenlea and Solar had similar grain yields above 40 kg N/ha.

The harvest index (HI) data from the Souris and Minnedosa sites had similar patterns although the HI's from Souris were marginally higher than those at Minnedosa (Table 5). The semi-dwarf cv's HY320, Marshall and Solar had higher HI's than Katepwa, Glenlea and Len. The HI'S of the semi-dwarf cultivars were relatively unaffected by increasing N application rates while those of Katepwa and Glenlea decreased markedly with increasing N fertilization.

At Miami the HI's of all 6 cv's decreased with increasing N rates, however the HI's of the semi-dwarf cv's were less affected than those of Katepwa and Glenlea.

The mid-season dry matter accumulation data from all 3 sites showed that Katepwa and Glenlea had the greatest responses to N fertilization during the vegetative growth phase. At rates of N >80 kg/ha, Katepwa and Glenlea had the highest mid-season dry matter accumulations. HY320, Marshall and Solar had lower midseason dry matter accumulations at each site. Len was intermediate between the other semi-dwarf cv's and Katepwa - Glenlea.

Dry matter accumulations at harvest displayed different patterns than at mid-season. Although the semi-dwarf cv's Marshall and Solar had grain yields higher than Katepwa and Glenlea, they did not show consistently higher total dry matter yields. At N rates >160 kg/ha HY320 had the highest dry matter accumulations at harvest. Len tended to have the lowest total dry matter yields.

Table 5. Harvest index* data from spring wheat cultivars grown at Souris, Minnedosa and Miami, Manitoba in 1985.

N applied kg/ha	Katepwa -----Site----- 1	2	3	Glenlea -----Site----- 1	2	3	Len -----Site----- 1	2	3	HY320 -----Site----- 1	2	3	Marshall -----Site----- 1	2	3	Solar -----Site----- 1	2	3
0	.44	.42	.39	.45	.42	.40	.44	.39	.40	.51	.47	.46	.50	.41	.45	.49	.44	.45
40	.42	.38	.37	.41	.39	.35	.42	.39	.38	.48	.45	.43	.45	.41	.42	.46	.44	.43
80	.39	.38	.33	.41	.37	.34	.41	.38	.38	.48	.46	.42	.47	.42	.42	.47	.44	.41
120	.39	.37	.34	.39	.38	.35	.42	.39	.37	.48	.47	.42	.47	.44	.41	.48	.46	.41
160	.39	.37	.33	.40	.38	.35	.40	.38	.37	.49	.45	.41	.48	.44	.41	.47	.45	.38
200	.39	.37	.33	.41	.37	.32	.40	.39	.35	.50	.47	.40	.47	.45	.42	.48	.45	.40
240	.39	.36	.32	.38	.37	.34	.40	.39	.35	.48	.45	.41	.48	.45	.41	.46	.45	.39

Std. error @ Souris = .004
Std. error @ Minnedosa = .003
Std. error @ Miami = .003
* Harvest index = grain:total above ground dry matter at harvest.

Site 1 - Souris
Site 2 - Minnedosa
Site 3 - Miami

Discussion and Conclusions

In 1985 the favorable growing conditions in western Manitoba were conducive to high N fertilization grain yield responses. All 6 cv's showed marked grain yield responses to N fertilizer application. At 2 of 3 test sites the Canadian semi-dwarf cv HY320 had higher grain yields and grain yield responses to N application than the hard red spring cv Katepwa, the utility cv Glenlea and the U.S. semi-dwarf cv's Len, Marshall and Solar. At the third site check yields were high but yield responses to N were low. Here HY320 had greater yields than Katepwa, Glenlea, Len and Solar. Marshall was equal in yield to HY320 at rates > 40 kg N/ha at this site.

The harvest index and dry matter accumulation data is consistent with the findings of other researchers who have observed that the yield advantage of semi-dwarf cv's in high yield environments is realized by a higher harvest index. Accordingly, N fertilization increased the vegetative growth of the standard height cv's Katepwa and Glenlea proportionately more than that of the semi-dwarf cv's. As a result the grain yields at N application rates > 40 kg/ha were higher and HI's lower for the semi-dwarf cv's HY320, Marshall and Solar than for Katepwa and Glenlea.

The fact that mid-season dry matter accumulation responses at Miami were similar to those at the other 2 sites and the fact that HI's at Miami were lower indicate that a factor or factors limited post anthesis growth and grain development at Miami. This resulted in lower grain yields. The exact cause of the poor yield performance at Miami is not readily apparent.

Acknowledgements

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AMMONIUM ION SOILS ORGANIC MATTER INTERACTION

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ABSTRACT

Four surface soils of varying organic matter content were used for fixation studies in laboratory incubations. These are designated as peat, clay, loam and sand. The soils were incubated for various period up to 1 week and with varying levels of labelled N^{15} $(NH_4)_2SO_4$ and urea.

The ammonium fixed from ammonium sulphate was both concentration and time dependent, with the absolute amount increasing with increase in concentration while the percent fixation decreased with increasing concentration. A comparison between ammonium sulphate and urea reveals that more nitrogen was fixed by all soils from urea than from ammonium sulphate.

Peat, with the highest organic matter content, has the highest level of fixation from both urea and ammonium sulphate. On the other hand sand with the lowest organic matter content has also the lowest fixation value, the level of fixation in sand was low enough for one to conclude that NH_4^+ fixation is unlikely to be a factor of import in the nitrogen economy of this soil. Clay and loam were intermediate in their behaviour. A quantitative linear relationship could not be established between fixation and organic matter content with this chosen soil sample, perhaps, because of the large difference that exists between the organic matter content of peat and the other mineral soils.

Irradiating the soil with 6 and 12 megarad of gamma ray was effective in arresting microbial activities but urease activity was not arrested. No significant difference in fixation level of sterilised and nonsterilised soils, thus it is concluded that fixation is not due to microbial activities.

INTRODUCTION

Fixation, immobilization and retention are some of the terms used to describe the phenomenom which makes total recovery of nitrogen fertilizers applied to the soil impossible by chemical extraction. Clay fixation, reaction with organic matter or utilization by soil microbes are some of the mechanisms put forward to explain such observations.

The ability of soil to retain applied nitrogen fertilizers is important both from the point of view of the total nitrogen economy of the soil and its availability to the current crop, and also from the consideration of the residual effect of this fertilizer in the

soil. Several workers have reported that plant recovery of nitrogen from urea and other ammonium yielding fertilizers is inferior to that of the nitrate-yielding ones (Rennie and Rennie 1973, Obi 1982).

An indication of the possibility of organic matter involvement in NH_4^+ fixation can be seen in the work of Sohn and Peech (1958), who reported that acid soils containing large amount of organic matter have the greatest NH_3 fixing capacity. The destruction of the soil organic matter with H_2O_2 markedly reduced the capacity of most soils to fix ammonia into non-exchangeable form. More direct, perhaps, was the result obtained by Burge and Broadbent (1961) in which ammonia fixation in organic soils of varying carbon content was linearly correlated with percent carbon. Their result was somewhat corroborated by Nyborg (1968), who reported that organic matter accounted for most of the fixation in mineral soils.

It was thus the aim of this study to investigate the role, if any, that organic matter of some Manitoba soils plays in the retention of NH_4^+ from urea and other ammonium carriers. Concentration and time effect on ammonium fixation will also be monitored and attempts will be made to see if such reaction or interaction can be characterized by physical parameters.

MATERIALS AND METHODS

Four surface soils (0-15 cm) of varying organic matter content were collected from cultivated fields for laboratory study. These soils were air dried and ground to pass through a 2 mm sieve and then stored in plastic containers at room temperature. Some of the relevant physical and chemical properties are shown in Table 1.

For fixation study use was made of two ammonium carriers, urea labelled with 98.6% ^{15}N and ammonium sulphate containing 95.5% ^{15}N. The use of labelled nitrogen carriers with high per cent enrichment was employed so as to be able to determine precisely and directly - using mass spectrometry - the amount of ferilizer nitrogen remaining in the soil after prolonged extraction with KCl and digestion by the modified Kjeldahl's method.

Five grams of soil was weighed into a plastic container with lid and labelled NH_4^+ carrier was added in solution to give the desired concentration and maintain the soil at field capacity the plastic container was then covered with the lid and incubated in a room thermostated at 20 c. Concentration of nitrogen used varied from 1.785-10.714 meq/100 g of soil (which corresponds to 250-1500 ug/g of nitrogen) so as to determine the effect of initial NH4 concentration on fixation.

The procedure for the extraction of mineral N in $(NH_4)_2SO_4$ treated soil is that described by Bremner and Keeney (1966) with slight modification. After incubating the soil sample to desired period of time, duplicate samples are then shaken for 1 hour with 1N KCl and then filtered under suction. The soil remaining in the filter paper is then leached with 75 ml of extracting solution in three parts of 25 ml each to ensure complete removal of inoganic nitrogen from the soil. The filtrate is then stored in a freezer for

the determination of exchangeable NH_4^+ while the residual soil is quantitatively transfered into plastic container for total nitrogen determination. For soils treated with urea the extraction procedure was that of Douglas and Bremner except that 1N kCl was used and filtration was carried out as described above.

In other experiment urease and microbial activities were arrested using gamma radiation at the dose of 2 megarad h^{-1} for 3 and 6 hours respectively. This was to allow urea to remain in the soil unhydrolized so as to see if urea is involved directly in the interaction with organic matter in the soil. Labelled urea was used and incubation process was as described for unsterilised soil.

CHEMICAL ANALYTICAL PROCEDURE

Organic matter in the soil was determined by the Walkey-Black method while mechanical analysis was done by pipet method after destroying the organic matter with H_2O_2 oxidation. Total nitrogen was determined by Kjeldahl's method modified to include clay fixed NH_4^+ by the method of Dhawal et al. The NH4-N in the digested soil was converted to N_2 gas with sodium hypobromite in a vacuum system as described by Cho (1985 personal communication). The N^{14}/N^{15} ratio was measured with mass spectrometer. Exchangeable NH4 in the filtrate was determined with an ammonium electrode after converting the NH4 to NH3 using 10N NaOH. Urea in the filtrate was determined colorimetrically using the method of Douglas and Bremner (1970).

RESULTS AND DISCUSSION

Comparison of level of fixation amongst the soils at a particular concentration shows that peat soil with the highest level of organic matter has the highest level of fixation throughout the incubation period. The result obtained for 1000 ug/g is shown in Fig. 1 and the same pattern is obtained for all the other four concentration levels used. A quick glance at the graph shows the dependency of fixation on the organic matter content of the soils but the result of clay and loam which have different organic matter content but virtually identical levels of nitrogen fixation does not lend total credence to this position. Though the difference in fixation level between clay and loam was insignificant, loam was consistently above clay at all concentration of ammonium sulphate used. Sand, which is low in both clay and organic matter content has the lowest level of fixation.

The effect of concentration and time on fixation by peat is shown in Fig.2 and this is representative of all the other four soils used. Fixation rate was initally fast at all concentration levels, but declines as the incubation time exceeds twenty-four hours. Fixation was both concentration and time dependent increasing with increase in concentration and incubation time, thus maximum fixation was obtained in all soils at the 1000 ug/g concentration level and after one week of incubation.The absolute value of fixed NH_4^+ increased with increase in initial concentration of ammonium sulphate but the per-cent fixation decreased with increasing concentration. This is in agreement with literature as stated by Nommik and Vahtras (1982). The pattern of fixation obtained for urea in all the

four soils is similar to that obtained with ammonium sulphate however as illustrated by Table 2, fixation here was higher in all soils than that of ammonium sulphate. The reason for this is not exactly known since ammonium determination in the filtrate shows that there is more ammonium ion (at any point in time) in soil incubated with ammonium sulphate than that with urea. The higher fixation with urea may be related to the nature of the fertilizer elements and their local pH effect on soil upon application. with the irradiated soils sterility test shows that the soils were sterile throughout the one week of incubation both at 6 and 12 megarad dosage. Despite the sterility of the soil hydrolysis of urea was unarrested and fixation level was virtually identical in both sterilised and nonsterilised soils Fig. 3. This result thus suggests that while radiation was effective in arresting microbial activities, urease enzyme was either not destroyed or hydrolysis occured through an uknown pathway-probably autocatalytic. The result obtained is not in agreement with recent work reported by Foster et al (1985), in which urea hydrolysis was arrested with 4.5 megarad of gamma radiation and fixation was not measured in irradiated soils treated with urea. Okereke and Meints (1985), attributed fixation measured within a period of 12 hours to microbial immobilisation, it is doubtful if microbial activities can be manifested within such short period of time. The identical nature of fixation in both sterilised and nonsterilised soils precludes microbial activities as being responsible for the fixation measured - at least in the short term.

In conclusion one can say that it is unlikely that gamma radiation is effective in arresting urease activity and if it is then the mechanism responsible for urea hydrolysis in sterilised soil needs further research. Also fixation measured in these soils is both time and concentration dependent and it is not due to microbial immobilisation.

Table 1. Chemical and physical properties of the soils used.

Properties	Soils			
Designation	Peat Organic	Clay Red river	Loam Elm creek	Sand Name Almassipi
pH	6.6	6.8	6.8	6.9
% O.Matter	72.79	7.33	5.77	5.0
NH_4^+ ug/g	23.2	12.2	10.7	7.4
NO_3^- ug/g	49.7	10.3	7.1	1.0
Total N_2 (%)	2.01	0.34	0.26	0.16
% Clay		73	33	5
% Silt		24	23	6
% Sand		3	44	89

Table 2. Fixation from urea and ammonium sulphate at 1000 ug/g and after 1 week of incubation in units of meq/100 grammes of soil.

	Urea	Ammonium sulphate
Peat	1.18	0.90
Clay	0.53	0.34
Loam	0.50	0.34
Sand	0.40	0.20

REFERENCE

Bremner, J.M. and D.R. Keeney. 1966. Determination and isotope-ratio analyses of different forms of nitrogen in soils. 3. Exchangeable ammonium, nitrate and nitrite by extraction distillature methods. Soil Sci. Soc. Am. Proc. 30: 517-582.

Burge, W.D. and F.E. Broadbent. 1961. Fixation of ammonia by organic soils. Soil Sci. Soc. Am. Proc. 25: 199-204.

Dhariwal, A.P.S. and F.J. Stevenson. 1958. Determination of fixed ammonium in soils. Soil Sci. 86: 343-349.

Douglas, L.A. and J.M. Bremner. 1970. Extraction and colormetric determination of urea in soils. Soil Sci. Soc. Am. Proc. 34: 859-862.

Foster, N.W., E.G. Beauchamp, and C.T. Corke. 1985. Immobilization of nitrogen-15-labelled urea in Jack Pine Forest Floor. Soil Sci. Soc. Am. Proc. 49: 448-452.

Nommik, H. and K. Kantras. 1982. Retention and Fixation of Ammonium in Soils. A.S.A. Monograph 22: 123-171.

Nyborg, M. 1968. Fixation of gaseous ammonia by soils. Soil Sci. 107: 131-136.

Obi, O.A. 1982. Isotope studies on crop utilization and soil fixation of nitrogen from urea, calcium nitrate and ammonium sulphate in several Manitoba soils. Ph.D. Thesis, University of Manitoba.

Okereke, G.U. and V.W. Meints. 1985. Immediate immobilization of labelled ammonium sulfate and urea nitrogen in soils. Soil Sci. 140: 105-109.

Rennie, R.J. and D.A. Rennie. 1973. Standard nitrogen versus nitrogen balance criteria for assessing the efficiency of nitrogen sources for barley. Can. J. Soil Sci. 53: 73-77.

Sohn, J.B. and M. Reech. 1958. Retention and fixation of ammonia by soils. Soil Sci. 85: 1-9.

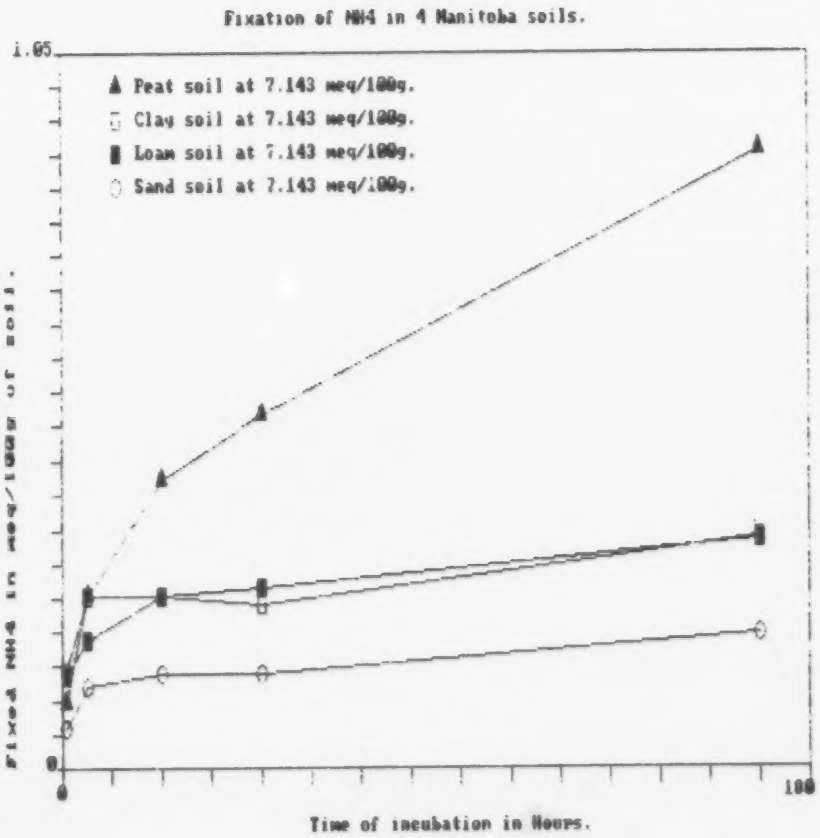
Fixation of NH4 in 4 Manitoba soils.
1.05
Peat soil at 7.143 meq/100g.
Clay soil at 7.143 meq/100g.
Loam soil at 7.143 meq/100g.
Sand soil at 7.143 meq/100g.
Fixed NH4 in meq/100gm of soil.
0
0
100
Time of incubation in Hours.

Fig. 1.

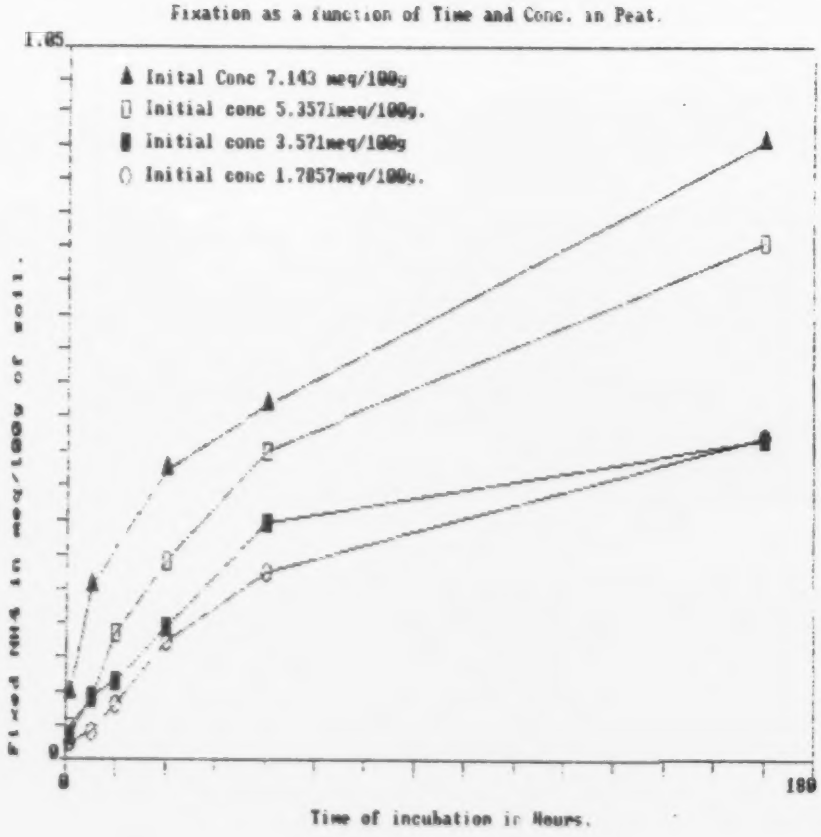
Fixation as a function of Time and Conc. in Peat.
1.65
Inital Conc 7.143 meq/100g
Initial conc 5.357meq/100g.
Initial conc 3.571meq/100g
Initial conc 1.7857meq/100g.
Fixed NH4 in meq/100g of soil.
0
0
180
Time of incubation in Hours.

Fig. 2.

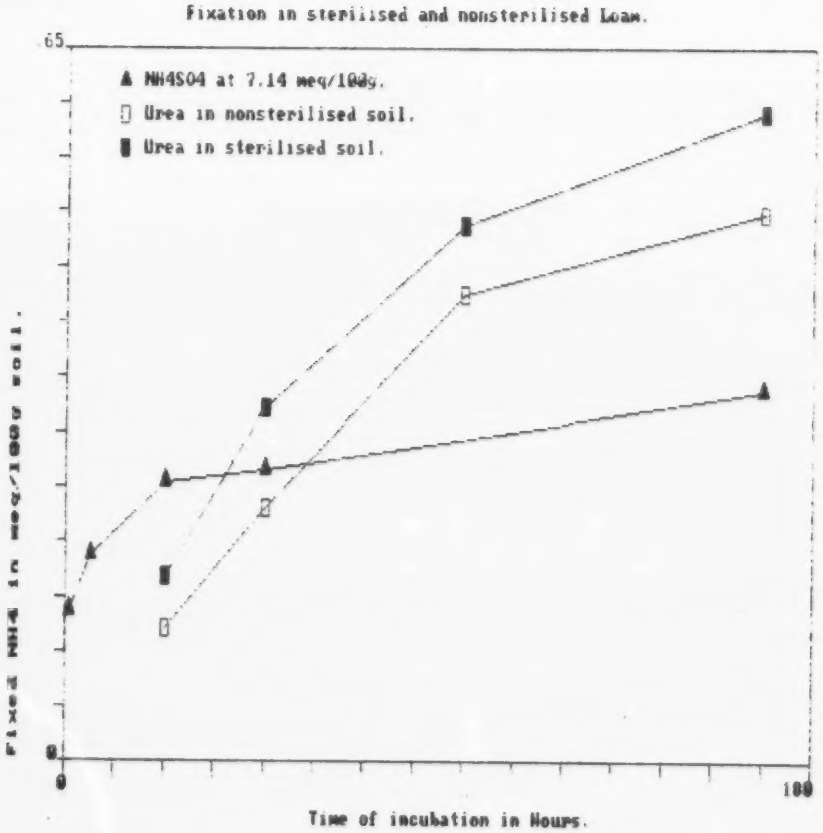
Fixation in sterilised and nonsterilised Loam.
65
▲ NH4SO4 at 7.14 meq/100g.
Urea in nonsterilised soil.
Urea in sterilised soil.
Fixed NH4 in meq/100g soil.
0
0
180
Time of incubation in Hours.

Fig. 3.

BANDING VERSUS INCORPORATION OF ELEMENTAL SULPHUR FERTILIZER

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INTRODUCTION

In the Prairie Provinces different sulphur fertilizers based on elemental sulphur vary greatly in their rates of conversion to soluble sulphate during the first or second year after field application (Solberg and Nyborg 1982). This is an important aspect of elemental sulphur fertilizers because only sulphate is taken up by crops. Even with those of the elemental sulphur fertilizer products which are the most rapid in conversion to sulphate, efficiency in the first year is less than that of soluble sulphate fertilizers (ammonium sulphate, sodium sulphate, calcium sulphate, and so on). Swan and Soper (1982) found that the liquid ammonium thiosulphate fertilizer was similar to gypsum in supplying sulphur for uptake by canola in the greenhouse, but Agri-Sul was not effective.

Most of our field work with elemental sulphur fertilizers has involved incorporation with and without subsequent cultivation. (Several materials were used: Agri-Sul was a commercial granular product 1 to 4 mm. in diameter consisting of 10% bentonite and 90% elemental sulphur; "solid pellets" was a commercial product with hard spheres of elemental sulphur 1 to 3 mm. in diameter; Urea S was a commercial product of urea granules 1 to 3 mm. in diameter impregnated with elemental sulphur particles of less than 50 um. in diameter; sublimed S consisted of finely divided elemental sulphur particles less than 150 um. in diameter; and "popcorn S" was a commercial hard, perforated, irregular elemental sulphur product ranging from 3 to 10 mm. in diameter.) Of these materials only urea S and sublimed S were substantially converted to sulphate by the end of the growing season (in most cases). We had assumed that banding or point placement would slow conversion to sulphate in the field as occurred under incubation (Solberg et al., 1982). Ukrainetz (1982) found in field experiments that yield and sulphur concentration was increased in canola by sodium sulphate and ammonium sulphate, but there was little or no increase with Agri-Sul, granular S and S powder whether they were incorporated or side banded. Swan and Soper (1982) obtained very low recoveries of sulphur from banded Agri-Sul in a canola greenhouse experiment. Otherwise, there has been little investigation of the rate of conversion with banding of elemental sulphur, as compared to incorporation.

The purpose of the present study was to compare the rate of conversion of several elemental sulphur sources as influenced by incorporation, by banding, and by an additional cultivation after initial incorporation.

MATERIALS AND METHODS

A cultivated Gray Luvisolic soil was used in an incubation experiment. The soil was SiL in texture; had a pH value of 5.9 and had a concentration of total N, total S and sulphate S of 1800, 150, 2.2 ug g^{-1}, respectively. The incubation was conducted in 1 litre plastic containers (930 g of air dry soil per container) at 24°C and the soil water content held between 85 and 90% field capacity. There were three

replicates with sampling at 21, 42 and 84 days. Several elemental sulphur products were used. "Product 1" is a dome shaped commercial product 2 to 4 mm. in length and 2 to 3 mm. in width consisting of 10% bentonite and 90% elemental sulphur. "Product 2" is a commercial granular product 1 to 4 mm. in diameter consisting of 10% bentonite and 90% elemental sulphur. Crushed "Product 2" has been ground so that the resultant particles are less than 150 um. in diameter. Sublimed S is solid, finely divided particles of elemental sulphur, formed directly from gaseous elemental S through sublimation. Two fractions were used; 34 to 45 um diameter and 75 to 150 um diameter. Flowable S is a commercial emulsion consisting of 52% elemental sulphur with particles less than 10 um. in diameter. Sulphur was added at 100 ppm. The treatments are listed in Table 2. Bands were placed at a depth of 4 to 5 cm. while the incorporated treatment was worked to a depth of 7 to 8 cm. A "cultivated" treatment was again mixed to a depth of 8 cm. after one week of incubation. Soil samples were extracted with 0.1 M $CaCl_2$ and SO_4-S determined by a modified Johnson-Nishita method.

A barley cropped field experiment was grown on a Black Chernozem having a pH of 6.0 and a concentration of total N, total S and soluble sulphate of 5700, 620, 8.0 ug g^{-1}, respectively. Urea S supplied sulphur at a rate of 30 kg ha^{-1} and additional urea was applied to give 100 kg ha^{-1} of nitrogen. The nitrogen and sulphur were applied together by (1) incorporating once; (2) incorporating twice; and (3) banding. Bands were spaced 45 cm. apart at a depth of 8 to 9 cm. Incorporation was made to a depth of 12 cm. and the second incorporation for treatment (2) was performed two days after initial fertilizer application. Plot design was a randomized complete block with subplots 1.83 m. by 6.86 m. There were four replicates. Barley was sown in early June and sampled in mid-August. Soil samples were taken in mid-November.

RESULTS AND DISCUSSION

In older work, little of the Urea S fertilizer (fine particles of elemental sulphur held in granules of urea) was recovered as sulphate by 84 days of incubation when the fertilizer was incorporated into two soils (Table 1). Results were similar when the granules were placed at a point. The recovery as sulphate of the fine sublimed S was slow with point placement but much more rapid with incorporation. The recovery as sulphate of the Urea S was high with "cultivation" (a thorough incorporation of the moist soil seven days after the initial incorporation of the Urea S into the dry soils immediately before the start of incubation). Apparently, dissolving of the urea followed by distribution of the fine elemental S particles was needed. Consequently, a second incubation experiment was conducted to find the influence of "cultivation" and banding on the rate of conversion of elemental sulphur to sulphate.

In the second incubation, the recovery of sodium sulphate was nearly complete with incorporation, banding and "cultivation" (Table 2). This behavior would be expected. "Product 1" and "Product 2" showed little recovery of sulphate sulphur. However, when "Product 2" was crushed to less than 150 um diameter the recovery was similar to incorporated sublimed S, and to incorporated Flowable S. Further, the treatment of "cultivation" seven days after the initial incorporation increased recovery of applied Flowable S and sublimed S at the first sampling (21 days). The "cultivation" effect was more pronounced with

Urea S (Table 1) as compared to sublimed S and Flowable S (Table 2).

Table 1. Net recovery (%), as SO_4-S, of fine elemental S materials after incubation in two soils. (S added at 25 ug g^{-1}, temp. 26 C; moisture at 85% of F.C.) Taken from Solberg at al., 1982.

		% recovery			
		Dark Gray		Black	
Materials	Placement	21 days	84 days	21 days	84 days
Sublimed S*	Incorp.	38	79	37	81
Sublimed S*	Point	14	14	27	46
Urea-S	Incorp.	6	16	26	12
Urea-S	Point	6	14	21	25
Urea-S	Cult. after incorp.	39	78	45	115

*Sublimed S is not a fertilizer product, but is a form of powdery small-particled elemental sulphur.

Banding caused a striking reduction in the rate of conversion of Flowable S and sublimed S to sulphate (Table 2). The reduction was apparently caused by the lessening of exposure of the elemental sulphur to the soil and thus less exposure to sulphur oxidizing microbes.

The banded Flowable S had greater values for conversion than sublimed S, but still the value for banded Flowable S remained low (22%) at 84 days (Table 2).

In the field experiment in 1984, on a soil not deficient in sulphur for a crop, the sulphate uptake of Urea-S by barley tended to be lowest with banding as compared to incorporation (Table 3). A second incorporation operation (two days after the first) tended to increase the sulphur uptake. Post-harvest soil sampling to 30 cm. depth gave clear differences among the treatments in soil sulphate content. The banding treatment had less sulphate than did the single incorporation treatment, but the twice incorporation treatment had more sulphate than did the single incorporation treatment. Apparently the conversion was least with banding and greatest with twice incorporation. Unfortunately, the results of the three treatments from the field experiment were confounded by application of nitrogen fertilizer.

Three field experiments with Urea-S were conducted in 1985 to further compare incorporation and banding. While we do not have the results completed, visual observations on removal of blocks of soil indicated that banding the Urea-S granules left the fine elemental sulphur particles intact, but the twice incorporated Urea-S had left few of the fine particles.

Table 2. Net recovery (%) of sulphate-sulphur from a Gray Luvisolic soil following incubation for 21, 42 and 84 days with various S sources. (At 85-90% F.C. and 24 C.)

Fertilizer	Method of application	% recovery 21 days	42 days	84 days
Nil	Incorporated	(3)*	(2)*	(4)*
Na_2SO_4	Incorporated	86	99	94
	Banded	85	90	96
	Cult./Incorp.	89	98	80
Flowable-S	Incorporated	26	54	59
	Banded	12	15	22
	Cult./Incorp.	39	60	43
Product 1 (clay + S^o)	Incorporated	1	0	3
	Banded	0	0	1
	Cult./Incorp.	0	4	2
Product 2 (clay + S^o)	Incorporated	1	0	2
	Banded	1	-2	3
	Cult./Incorp.	0	3	1
Product 2-crushed	Incorporated	43	53	63
Sublimed S** (75-150 um)	Incorporated	27	47	58
	Banded	7	6	13
	Cult./Incorp.	32	60	56
Sublimed S** (34-45 um)	Incorporated	26	55	58
	Banded	4	1	9
	Cult./Incorp.	41	60	55
	LSD	2	3	4

* Not recovery of fertilizer S, but the content of SO_4-S in non-fertilized soil (ug g^{-1})

** Sublimed S is not a fertilizer product, but is a form of powdery, small-particled elemental sulphur

Table 3. Uptake of S by barley in early August, and soil content of SO_4-S in November, with Urea-S added in field experiment. (Rate of S application 30 kg ha^{-1}; soil was a Black Chernozem).

Placement of Urea-S	S uptake by barley (kg ha^{-1})	SO_4-S in soil (0-30 cm) in late fall (kg ha^{-1})
Incorporated once	11.4	15.2
Incorporated twice	12.5	25.0
Banded (45 cm spacing)	10.7	8.7
LSD	2.0	4.2

GENERAL DISCUSSION AND CONCLUSIONS

Several practical points concerning use of elemental sulphur fertilizers will be mentioned before the conclusions.

Crops take up sulphate-sulphur, and soluble sulphate salts (e.g. ammonium sulphate, sodium sulphate) are immediately available to a crop. Elemental sulphur is not available, but is available after it is converted to sulphate by soil microbes. The speed of conversion varies greatly with the type of elemental sulphur fertilizer and the kind of fertilizer placement. Generally, when a modest rate of sulphur fertilizer is applied in the spring, a sulphate fertilizer is more efficient per weight of sulphur in supplying the crop for at least several months than is elemental sulphur. However, if the elemental sulphur fertilizer is relatively quick to convert to sulphate and the rate of application of the fertilizer is increased, the crop could be sufficiently supplied with sulphate. In addition, the recommended rates of sulphate fertilizers tend to be higher than is needed, in our experience. A sulphur-deficient crop of a cereal grain or grass hay only needs to take up approximately 5 to 6 kg ha^{-1} more of sulphate-sulphur fertilizer.

There is a substantial residual effect of elemental sulphur in the year after application, but not when a slow converting fertilizer is used (e.g. solid sulphur versus small particles of sulphur). Urea S is made of small particles of elemental sulphur held in granules of urea, and the speed of conversion to sulphate is much improved when a second cultivation follows the incorporation cultivation. Apparently, the urea dissolves after incorporation, and on the second cultivation the fine particles of elemental sulphur become mixed into the soil. However, S urea broadcast on grass land became relatively rapidly available to bromegrass (Solberg, 1982). To speculate, raindrops may disperse the fine sulphur particles. In the

present study, the two products of bentonite and fine particles of elemental sulphur gave surprisingly little conversion, even when the fertilizers were incorporated followed by "cultivation". Of course, "cultivation" in a laboratory container is not the same as cultivation in the field.

The principle of achieving a good proportion of elemental sulphur converted to sulphate available to the first crop after application is as follows. (1) The use of small particles, whether held as an emulsion or as a granule which rapidly releases the small particles (while dry, powdered elemental sulphur is effective, its field use is not practical); (2) the cultivation of the soil to mix the small particles into the soil; and (3) the avoidance of leaving elemental sulphur in a band.

The restricted conclusions of the present work are as follows.

(1) Under incubation, banding as compared to incorporation slowed conversion of elemental sulphur to sulphate with Flowable S and sublimed S.

(2) In an older incubation experiment, the rate of conversion for Urea S was increased by "cultivation" after the initial incorporation of the fertilizer.

(3) Under incubation, two commercial products made of bentonite and elemental sulphur had little conversion to sulphate regardless of type of placement.

(4) In the field with Urea S, the conversion to sulphite was slowed by banding but speeded by cultivation after initial incorporation.

REFERENCES

1. Solberg, E.D., et al.: "Oxidation of elemental sulphur used as a fertilizer". In Proceedings of the 19th Annual Alberta Soil Science Meeting. Agriculture Alberta. pp. 241-252 (February, 1982).

2. Solberg, E.D., and Nyborg, M.: "Comparison of sulphate and elemental sulphur fertilizers". In Proceedings of International Sulphur '82 Conference; London, England, pp. 843-852 (November, 1982).

3. Swan, M.J., and Soper, R.J.: "Availability of sulphur from gypsum, Agrisul and ammonium thiosulfate". In Proceedings of the 25th Annual Manitoba Soil Science Meeting, University of Manitoba, Winnipeg, Manitoba, pp. 136-144 (1982).

4. Ukrainetz, H.: "Oxidation of elemental sulphur fertilizers and response of rapeseed to sulphur on a Gray Wooded soil". In Proceedings of the 19th Annual Alberta Soil Science Meeting. Agriculture Alberta, Soils Branch, Edmonton, Alberta, pp. 241-252 (February, 1982).

CALCIUM-MAGNESIUM-POTASSIUM INTERACTIONS IN HIGH MG SYSTEMS

C.A. Grant and G.J. Racz

Introduction

Ca, Mg and K are the dominant cations in plant nutrition. Ca and Mg also tend to dominate on the cation exchange systems of soils, particularily in arid regions. In Manitoba, many of the soils in the eastern portion of the province have very high levels of Mg and Ca on the exchange and in the soil solution. High levels of Mg in the soil system have been suspected of leading to reduced crop yields. However, the majority of studies dealing with Mg have focused on Mg deficiencies rather than on the effects of excess levels of Mg. As well, Mg has been observed to interact with Ca and K both in the soil system and in the nutrition of the plant (Mengel and Kirkby 1979). Therefore, both the absolute level of Mg in the soil system and its abundance relative to other plant nutrients such as Ca and K may be important in influencing crop productivity.

The primary objective of this study was to determine if high concentrations of Mg led to a reduction in barley yield. However, in soil systems, high levels of Mg are generally associated with other factors, such as high Ca levels, high pH and fine soil texture, which also may influence yield. In order to eliminate the effect of other correlated soil characteristics, chemical effects of high concentrations of Mg and Ca were examined initially in solution culture, with pH and the levels of other nutrients strictly controlled. Subsequent experiments were later conducted to examine effects of high Mg and Ca concentrations in soil systems.

Materials and Methods

In all hydroponic studies conducted, barley seeds were soaked for 24 hours in aerated distilled water and planted in flats of vermiculite. Seedlings were transferred at the 1 leaf stage in groups of 24 to black painted plastic containers containing 10 litres of aerated treatment solution. All solutions were modifications of a full strength Hoagland's California #1 solution (Hoagland and Arnon 1950). All modifications to solutions were made using nitrate salts and the levels of nitrogen adjusted to a constant level using NH_4NO_3. The pH was adjusted to 6.5. Solutions were changed every 3 days during the study period. Plants were harvested after 14 and 28 days of growth. Roots and shoots were weighed separately and nutrient analysis for Ca, Mg, K, Mn, Zn, Cu and Fe were conducted using atomic absorption spectrophotometry.

Two series of experiments were conducted. The first, using Bonanza barley, was concerned with the effect of both concentration and

ratio of Ca and Mg on the growth of barley. Treatments were replicated twice and the experiment was conducted twice. Solution compositions were as follows:

Table 1: Solution formulations in experiment 1.

Treatment	Mg	Ca	Mg:Ca ratio
	----------mM----------		
1	2.0	0.5	4:1
2	2.0	1.0	2:1
3	2.0	2.0	1:1
4	2.0	4.0	1:2
5	8.0	2.0	4:1
6	8.0	4.0	2:1
7	8.0	8.0	1:1
8	8.0	16.0	1:2
9	8.0	32.0	1:4

Each solution contained 1 mM Na. Nitrogen was added as NH_4NO_3 to adjust the N concentration in solutions 1 to 7 to 49 mM, the levels found in treatment 8. N was adjusted to the level of treatment 8 rather than 9 because the level in treatment 9 was considered excessively high.

A second experiment was conducted to examine the effect of Ca and Mg concentrations of ratios on the dry matter yield and nutrient relations of Johnston and Bonanza barley. A full factorial design was used with 12 solutions consisting of all combinations of Ca at 2, 4, and 16 mM, and Mg at 2, 4, 8 and 16 mM. Each treatment was replicated twice and each pan contained 12 plants each of Johnston and Bonanza barley.

In a third experiment, 10 soils varying in Mg content were selected and evaluated for their effect on growth and nutrient relations of Johnston barley. Two runs of three replicates each were conducted. Soils were mixed thoroughly with 200 ppm N as ammonium nitrate, 50 ppm P as monoammonium phosphate, and 50 ppm S as ammonium sulfate. Four barley plants were grown to full heading in pots containing 2.2 kg of soil. Soils were initially taken to field capacity and maintained within 15% of field capacity by the addition of distilled water. Plant dry matter yield was measured after 4 weeks and tissue was analyzed for Ca, Mg, K, Mn, Zn, Cu and Fe.

To evaluate the concentrations of Ca, Mg, and K in the soil solution, soil samples were taken to field capacity by addition of distilled water and incubated for one week. Soil solution was then

extracted from the test soils by centrifuging for one hour at 15000 rpm.

Results

1. Hydroponic studies

(a) Dry matter yield

The oven dry weight of Bonanza barley roots and shoots from experiment 1 are shown in figure 1. Yield increased with increasing Ca levels in the solution until concentration reached 4 to 8 mM. Yield then decreased as the Ca in the solution increased. The lowest yields were obtained at the highest and lowest Ca concentrations. There was no apparent effect of Mg concentration on dry matter yield, however, concentration of Mg in the solutions was not increased above 8 mM.

In the subsequent experiment, (figures 2 and 3) shoot dry weight again increased with the initial increments of both Ca and Mg and decreased as the concentration of either Ca or Mg increased above 8 mM. Shoot dry weight displayed a Mg x cultivar interaction, indicating that Johnston was more sensitive to high levels of Mg than was Bonanza.

In both experiments, actual concentration of Ca and Mg in the solution was more important in influencing dry matter yield than was the ratio of Ca to Mg.

(b) Nutrient concentrations

As would be expected, in both experiments Ca concentration in the shoot increased with increasing concentration of Ca in the solution. Figure 4 illustrates Ca concentration as a function of Ca and Mg concentration in the solution in experiment 2. In both experiments, a negative Ca x Mg interaction was observed, indicating that increasing the Ca concentration of the solution did not produce as great an increase in the Ca concentration of the tissue as the Mg concentration of the system increased. Mg concentration in the shoot increased with increasing Mg concentration in the tissue in both experiments. Mg concentration in the tissue in experiment 2 is illustrated in figure 5.

Ca:Mg ratio in the tissue in both experiments was very closely related to the Ca:Mg ratio in the solution (figure 6). Ca:Mg ratio in the tissue increased with increasing Ca concentration in the solution and decreased with increasing Mg concentration in the solution. However, Ca:Mg ratio in the solution was the best

It has been suggested (Welte and Werner 1963; Salmon 1963) that high concentrations of Mg or Ca could interfere with K concentration in the tissue. However, K concentration of the tissue was not influenced by either Ca or Mg in the first experiment. In the second experiment, concentration of K in the tissue tended to increase with increasing concentration of either Ca or Mg in the tissue (figure 7). But, the bulk of this effect was associated with the decrease in dry matter yield associated with the high Ca and Mg concentrations in the solution. Since, K uptake was not influenced as greatly by the high concentrations of Ca and Mg as was dry matter yield, the concentration of K in the tissue increased.

Zn concentration of the shoot was measured in the first experiment and Mn, Zn, Cu and Fe concentration in the shoot was measured in the second experiment. Cu and Fe appeared to be primarily influenced by the dry matter yield of the system, increasing in concentration when dry matter yield was suppressed. At low concentrations of Mg and Ca in solution, Mn and Zn concentration and uptake were also primarily determined by dry matter yield. However, at very high concentrations of Mg or Mg plus Ca in the nutrient solution, concentration of Mn and Zn in the shoot and total uptake of Mn and Zn increased substantially. Figure 8 shows that Mn uptake peaked at 16 mM Ca and 8 mM Mg, in spite of the low yield associated with this solution. As was observed for Mn the highest uptake of Zn was associated with high concentrations of Ca and Mg (figure 9), in spite of the low yields associated with this highly concentrated solution. Concentration of Mn and Zn in the tissue were highly correlated with one another ($r=0.80$). It appeared that in the presence of high concentrations of Mg and Ca, the plants were incapable of limiting the uptake of Zn and Mn.

If high concentrations of Ca and Mg lead to increased permeability of the plasma membrane, it is possible that the increase in uptake of Mn and Zn observed in the nutrient culture experiment could be due to a loss of the ability of the membrane to exclude these nutrient. A 'leaky' membrane could allow relatively free passage of Mn and Zn into the cytoplasm. However, since concentration of Zn and Mn in nutrient culture tends to be substantially higher than that found in a natural soil solution, it is unlikely that concentration of these nutrients in the tissue would reach excess levels in a soil system.

To better understand the effect of high concentrations of Ca and Mg on membrane function, leakage of Rb from intact barley seedlings pretreated with Rb was examined. The sum of Ca plus Mg in the treatment solutions totalled 16 mM, but the ratios of Ca:Mg were 14:2, 12:4, 8:8, 4:12, and 2:14. Lowest efflux occurred when the ratio of Ca:Mg was 1.0 and both Ca and Mg were present at a concentration of 8 mM (figure 10). Increasing either Ca or Mg at the expense of the other cation led to increased leakage.

II. Soil studies

The exchangeable and soil solution content of Ca, Mg and K in the test soils are given in table 2. Soil solution concentration of Mg and Ca tended to be somewhat lower than concentrations associated with reduced yield in the hydroponic nutrient solutions. K concentrations of the soil solution was generally substantially lower than concentrations of K in the nutrient solutions.

Correlation coefficients among soil parameters are given in table 3. Ca and Mg content of the soils were positively correlated with one another and negatively correlated with K, Zn and Mn content.

As in the nutrient culture studies, dry matter yield was negatively correlated with Mg and Ca concentration in the soil solution (table 4), but was positively correlated with K concentration in th soil solution and with extractable Zn and Mn.

Ca concentration in the tissue was unrelated to Ca content of the soil as measured by exchangeable or solution concentration. However, Ca concentration of the tissue was negatively correlated with Mg content of the soil. Mg concentration of the tissue increased with increasing Mg content of the soil solution. Concentration of Mg in the tissue was more closely correlated with solution concentration of Mg than with exchangeable Mg. K concentration of tissue was positively correlated with the K content of the soil and exchangeable K was more closely related to tissue levels of K than was solution concentration.

Mg and Ca concentration of the tissue were negatively correlated with dry matter yield. This was presumably due primarily to biological dilution. Zn and Mn concentrations in the tissue were positively correlated with dry matter yield and negatively correlated with Mg content of the soil. Zn and Mn concentrations in the tissue in low yielding soils were below critical levels listed by Mortvedt et al, 1972.

The positive correlation of tissue concentration of Mn and Zn with dry matter yield and the low levels of these nutrients in the tissue seems to indicate that low availability of Mn and Zn may have been restricting yield. Although dry matter yield was negatively correlated with the soil content of Mg and Ca, the levels of these nutrients in the solution were below the levels which had been observed to reduce dry matter yield in the hydroponic culture. High levels of Mg and Ca in the soil were associated with low levels of Mn, Zn and K. It appears probable that the reduced yield associated with high levels of Ca and Mg in the soil was actually due to deficiencies of Zn and Mn.

Conclusions

From the experiments discussed, the following conclusions can be drawn:

(a) Concentrations of either Ca or Mg greater than 8 mM in solution culture may lead to reductions in dry matter yield of barley. Johnston barley appeared more sensitive to high concentrations of Ca or Mg than did Bonanza.

(b) Ca concentration in the tissue increased with increasing concentration of Ca in the nutrient solution, while concentration of Mg in the tissue increased with increasing concentration of Mg in the nutrient solution. Concentration of K in the tissue was not reduced by increasing concentration of Ca or Mg in the nutrient solution.

(c) Concentration of Zn and Mn in the tissue and their total uptake by the plant increased substantially at high concentrations of Ca or Mg in the nutrient solution. Leakage of solutes from intact barley roots also increased at high concentrations of Ca or Mg in the solution. These facts support the idea that high concentrations of Ca or Mg in solution may lead to an increase in membrane permeability.

(d) Soil solution concentration of Ca and Mg are generally lower than concentrations which lead to decreased yield in nutrient culture. However, dry matter yield was negatively related to Mg and Ca levels in the soil.

(e) Zn and Mn concentrations in the soil and tissue were positively correlated with dry matter yield and negatively correlated with soil levels of Mg and Ca. Therefore, reduced dry matter yield associated with soils high in Mg may be related to deficiencies of Mn and Zn associated with high Mg soils.

References

HOAGLAND, D.R. and ARNON, D.I. 1950. The water culture method for growing plants without soil. Cal. Agric. Expt. Sta. Circular 347.

MENGEL, K. and KIRKBY, E.A. 1979. Principles of Plant Nutrition. 2nd Edition. International Potash Institute. Bern.

MORTVEDT, J.J., GIORDANA, P.M. and W.L. LINDSAY, Editors. 1972. Micronutrients in Agriculture. Soil Science Society of America, Inc. Madison. 666 pages.

SALMON, R.C. 1963. Magnesium relationships in soils and plants. J. Sci. Fd. Agric. 14:605-610

WELTE, E. and WERNER, W. 1963. Potassium-magnesium antagonism in soils and crops. J. Sci. Fed. Agric. 14:180-186.

Table 2. Exchangeable and soil solution concentration of Ca, Mg and K in test soils.

Soil	Exchangeable			Solution Concentration		
	Ca	Mg	K	Ca	Mg	K
	ppm			mM		
1	3050	460	1260	2.15	0.94	4.56
2	4800	2600	510	1.77	2.92	0.35
3	5490	2510	430	2.66	3.05	0.28
4	3850	1570	610	2.26	1.75	0.59
5	6060	2110	230	2.14	3.49	0.17
6	3370	2240	450	0.68	1.30	0.18
7	5140	1850	490	1.99	1.86	0.29
8	4700	1870	230	2.25	4.36	0.27
9	4380	560	370	2.51	1.30	0.42
10	4630	750	480	1.66	0.69	0.23

Table 3. Correlation coefficients between exchangeable and solution Ca, Mg and K and extractable Zn and Mn in test soils.

	[Ca]	Ca ex	[Mg]	Mg ex	[K]	K ex	Mn	Zn
[Ca]	--	0.45**	0.58***	NS	NS	NS	-0.44**	NS
Ca ex	0.45**[1]	---	0.63***	0.61***	-0.68***	-0.73***	-0.68***	-0.53**
[Mg]	0.58***	0.63***	---	0.63***	-0.44**	-0.61***	-0.74***	-0.49**
Mg ex	NS	0.61**	0.63***	---	-0.65***	-0.59***	-0.60***	-0.44**
[K]	NS	-0.68***	-0.44**	-0.65***	---	-0.94***	-0.57***	0.92***
K ex	NS	-0.73***	-0.61***	-0.59***	0.94***	---	-0.68***	0.93***
Mn	-0.44**	-0.68***	-0.74***	-0.60***	-0.57***	-0.68***	---	0.66***
Zn	NS	-0.53**	-0.49**	-0.44**	0.92***	0.93***	0.66***	---

1 * $P < 0.05$ ** $P < 0.01$ *** $P < 0.0001$

Table 4. Correlation coefficients between soil nutrient measures, plant yield and nutrient parameters.

	Dry matter yield	[Ca]	Ca ex	[Mg]	Mg ex	[K]	K ex	Mn	Zn
Dry matter Yield	---	NS	-0.37*	-0.36***	NS	0.51**	0.58**	0.59**	0.80**
Ca in tissue	-0.35***[1]	NS	NS	NS	-0.39**	NS	NS	NA	NA
Mg in tissue	-0.27**	NS	0.53**	0.72***	0.69***	-0.51*	-0.63***	NA	NA
K in tissue	NS	NS	NS	NS	NS	0.43*	0.47*	NA	NA
Ca/Mg in tissue	NS	NS	-0.50**	-0.74***	-0.92***	0.58***	-0.67***	NA	NA
Mn in tissue	NS	NS	NS	NS	-0.42*	NS	0.46*	0.70***	0.43*
Zn in tissue	0.56**	-0.48*	-0.75***	-0.68**	-0.72***	0.77***	0.77***	0.76***	0.85***

[1] * $P < 0.05$ ** $P < 0.01$ *** $P < 0.0001$

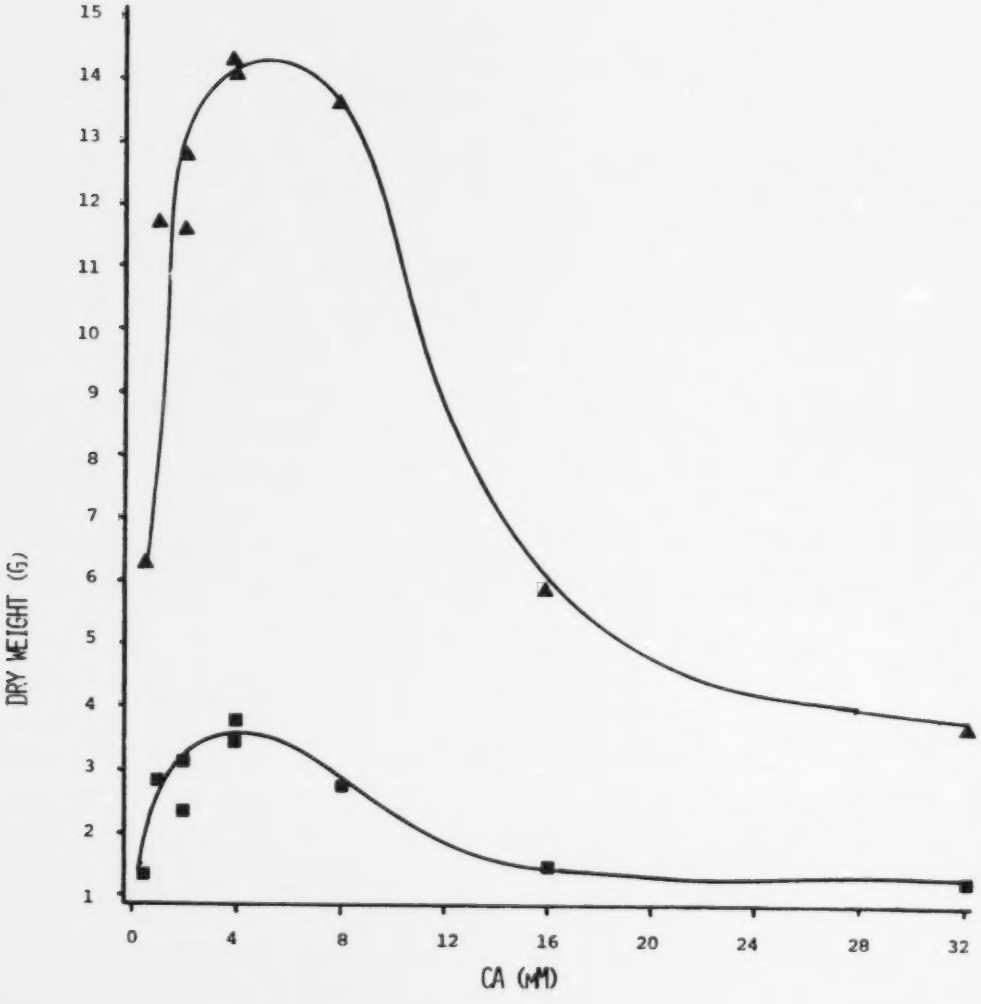

FIG 1: ROOT AND SHOOT DRY WEIGHT AS A FUNCTION OF CA CONCENTRATION OF THE SOLUTION AT 2 AND 4 MM MG, HARVEST 2

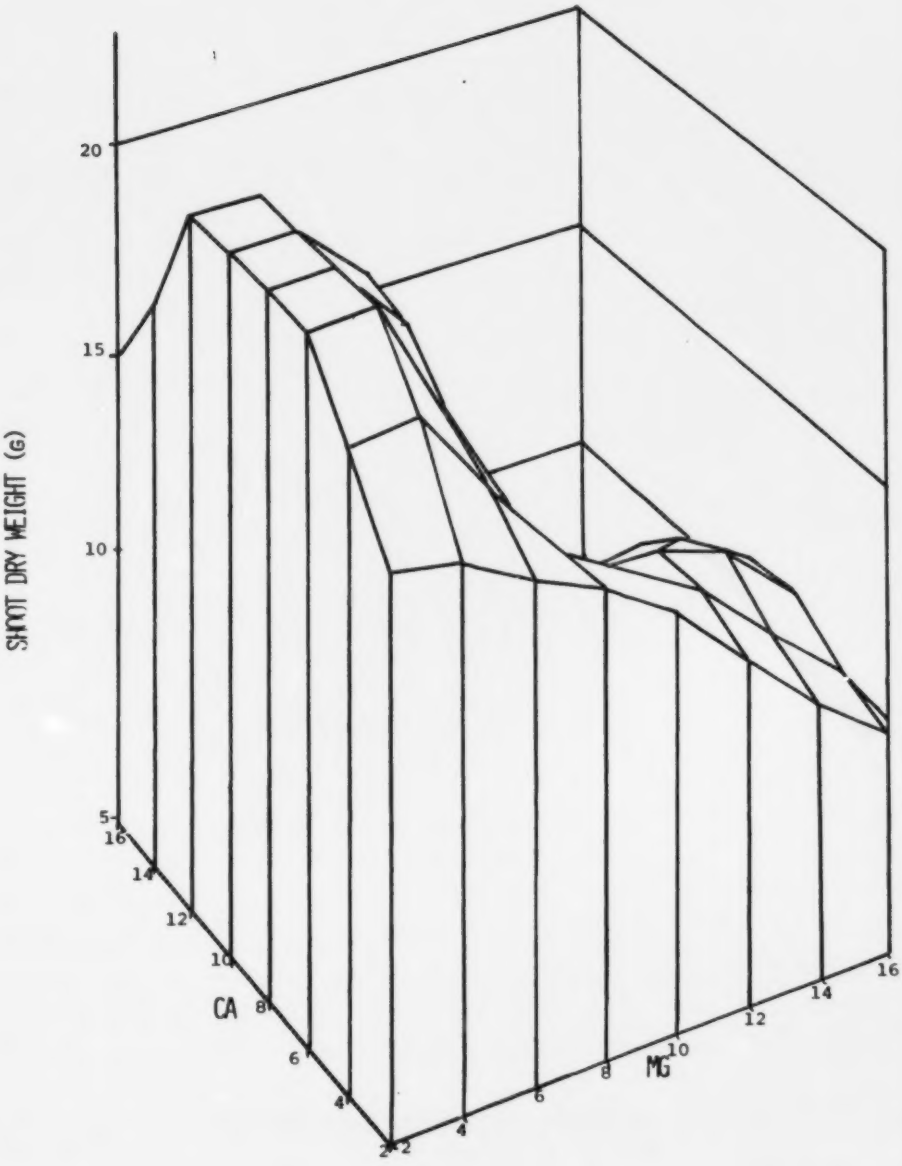

FIG 2: SHOOT DRY WEIGHT OF JOHNSTON BARLEY AS A FUNCTION OF CA AND MG IN THE SOLUTION

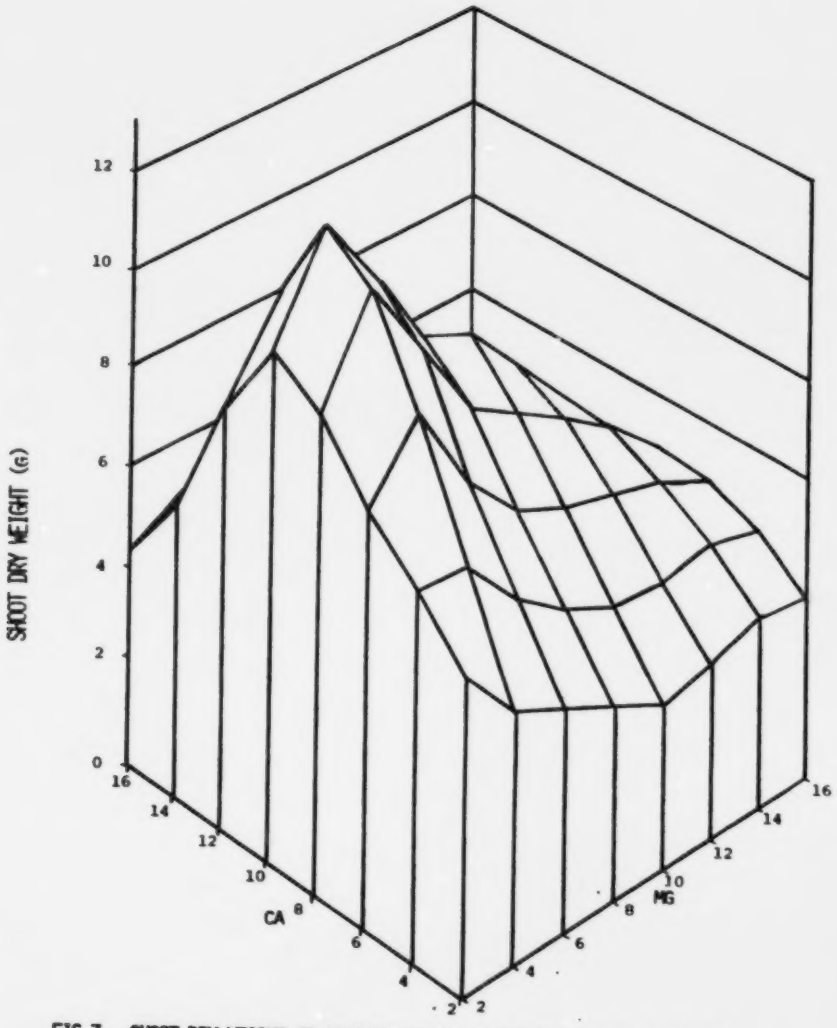

FIG 3: SHOOT DRY WEIGHT OF BONANZA BARLEY AS A FUNCTION OF CA AND MG IN THE SOLUTION

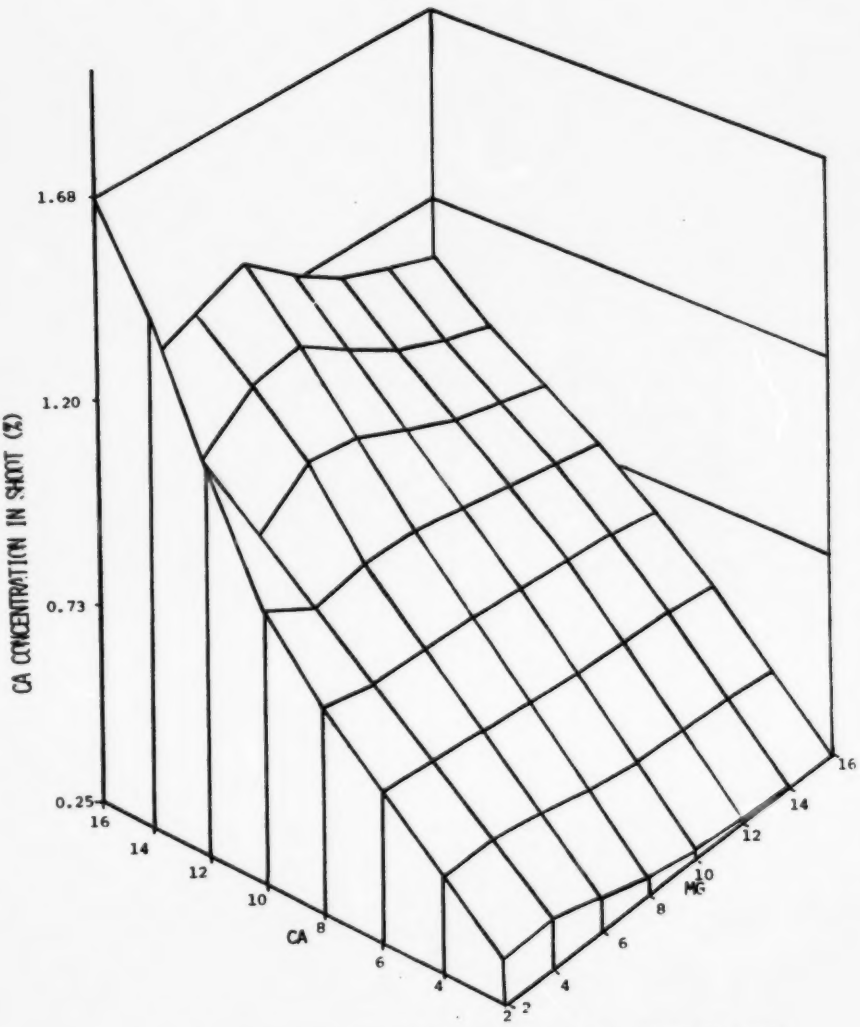

FIG 4: CA CONCENTRATION OF BARLEY SHOOTS AS A FUNCTION OF CA AND MG IN THE SOLUTION

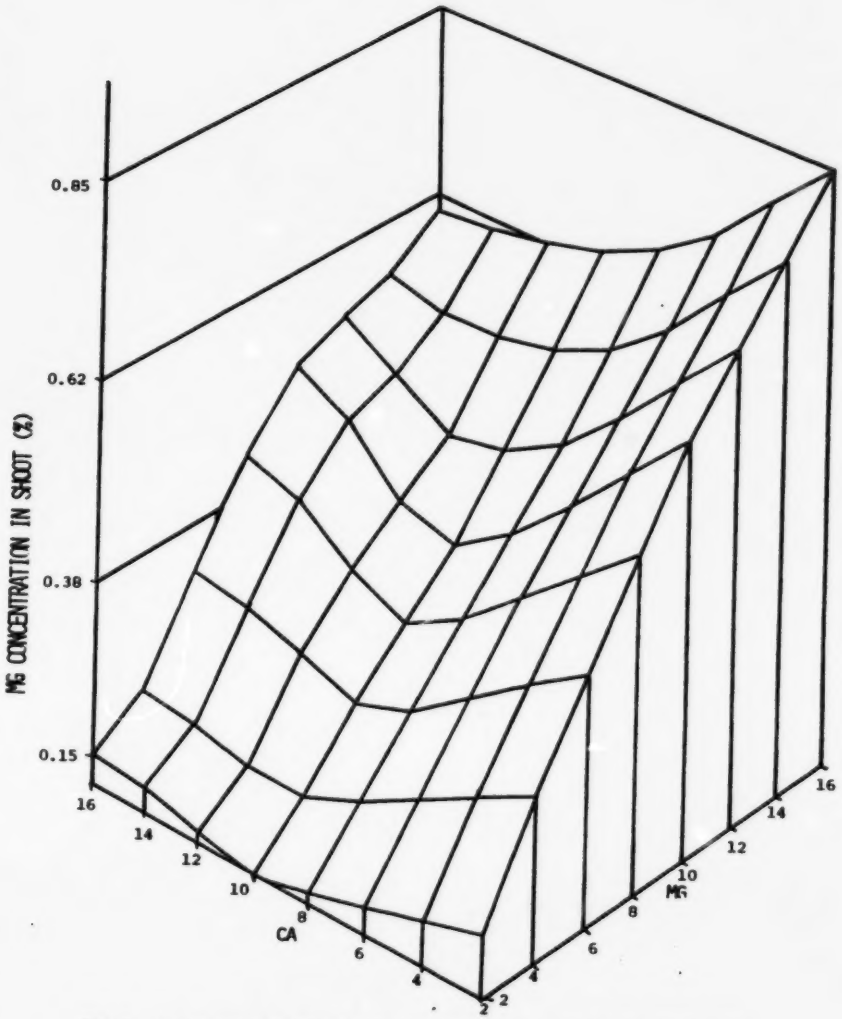

FIG 5: MG CONCENTRATION OF BARLEY SHOOTS AS A FUNCTION OF CA AND MG IN THE SOLUTION

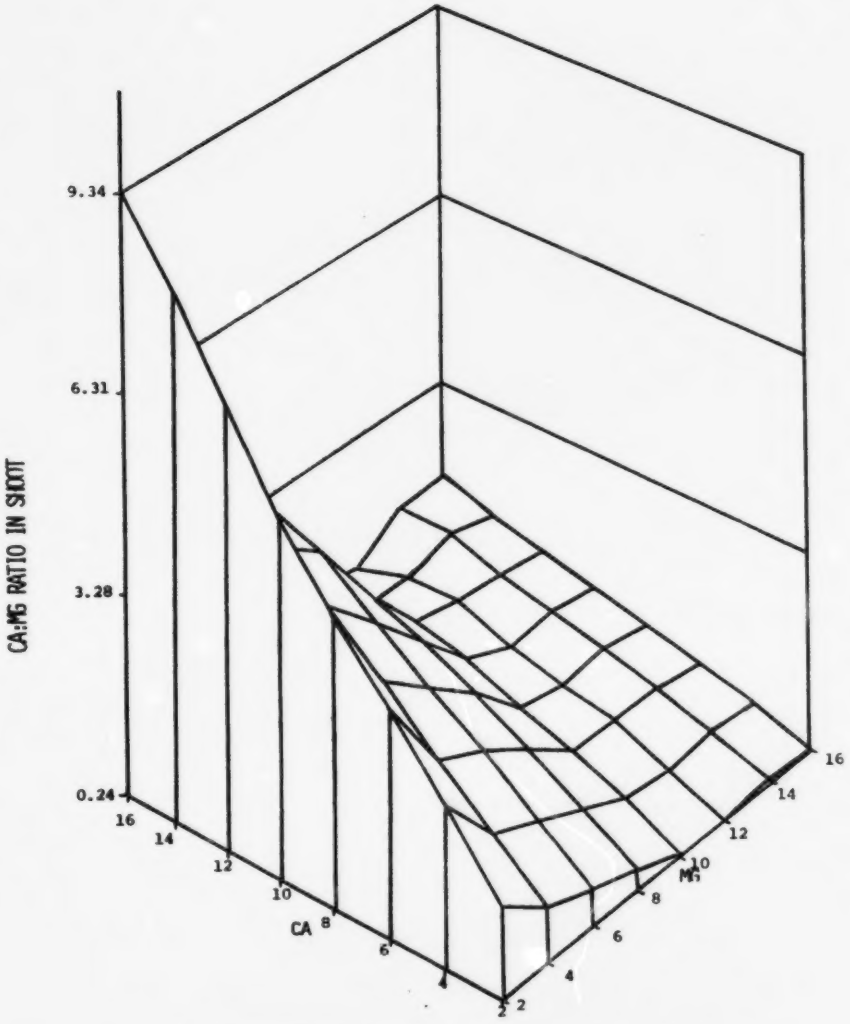

FIG 6: CA:MG RATIO OF BARLEY SHOOTS AS A FUNCTION OF CA AND MG IN THE SOLUTION

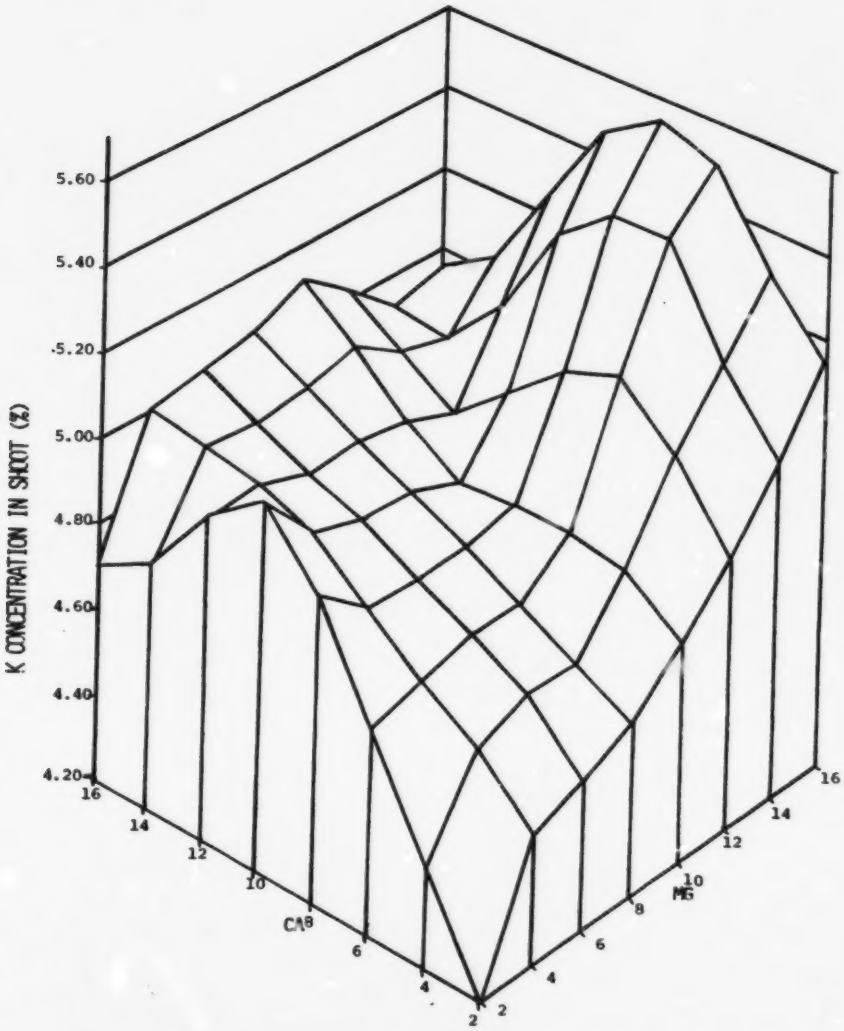

FIG 7: K CONCENTRATION OF JOHNSTON BARLEY SHOOTS AS A FUNCTION OF CA AND MG IN THE SOLUTION

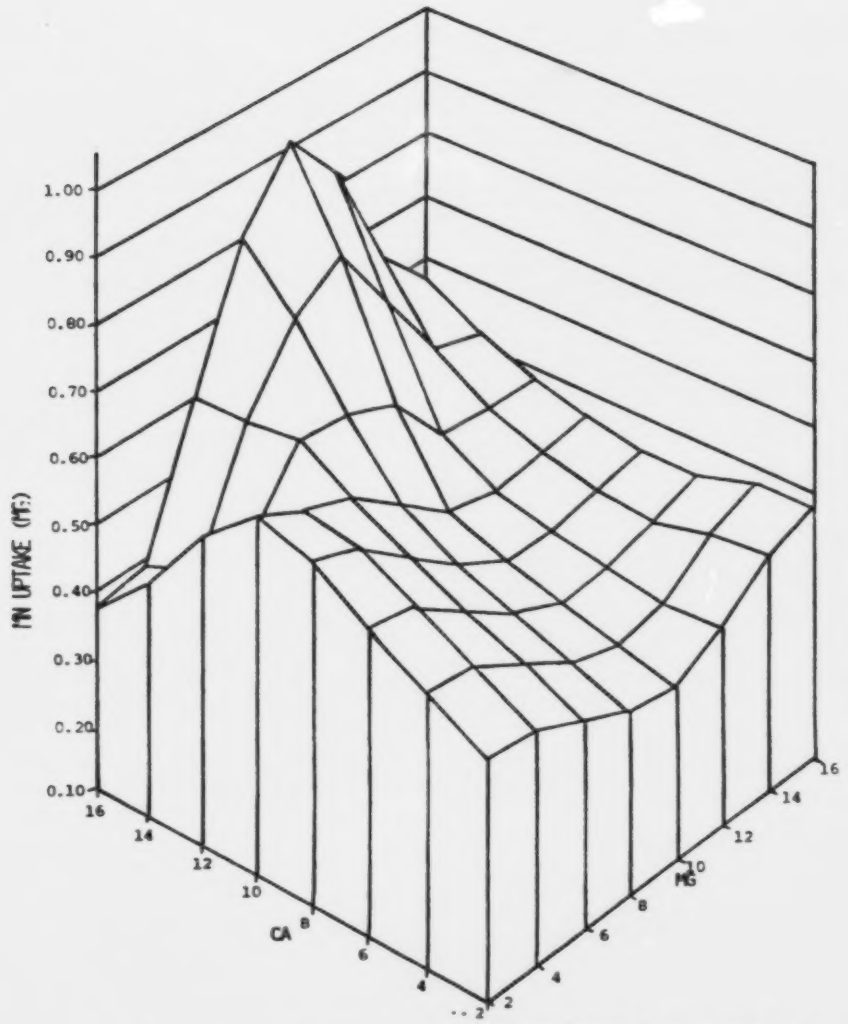

FIG 8: MN UPTAKE BY SHOOTS OF BARLEY PLANTS AS A FUNCTION OF CA AND MG IN THE SOLUTION

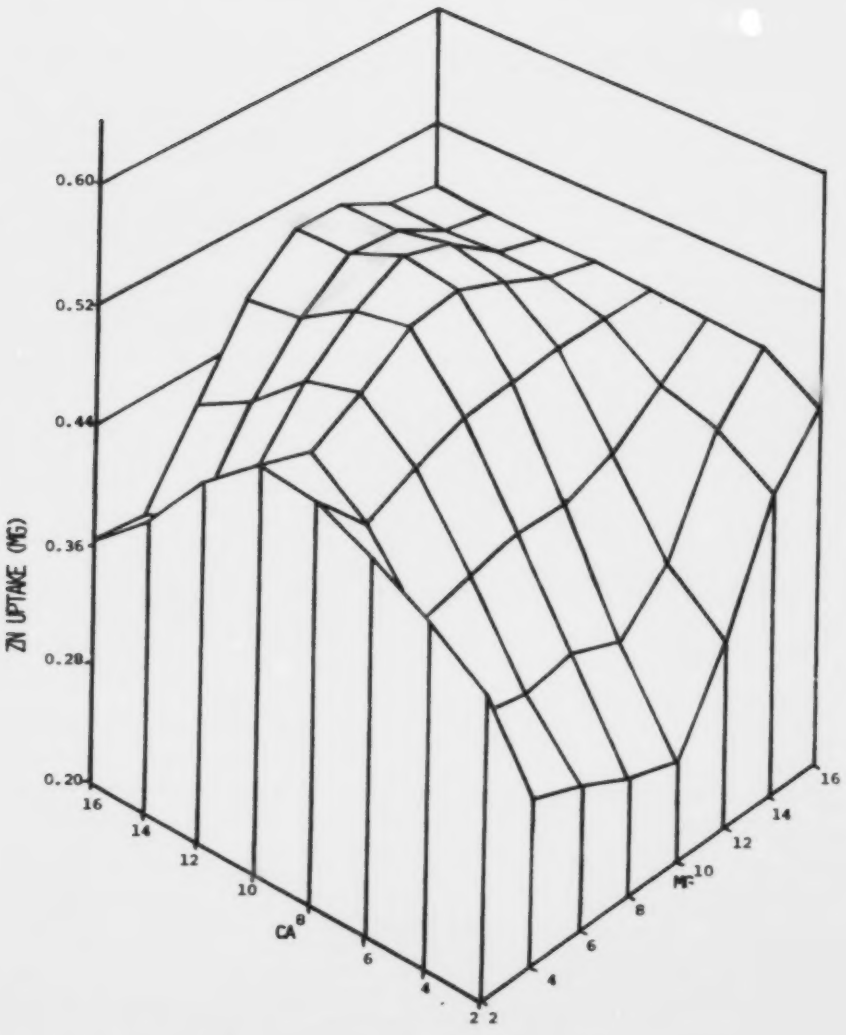

FIG 9: ZN UPTAKE BY SHOOTS OF BONANZA BARLEY AS A FUNCTION OF CA AND MG IN THE SOLUTION

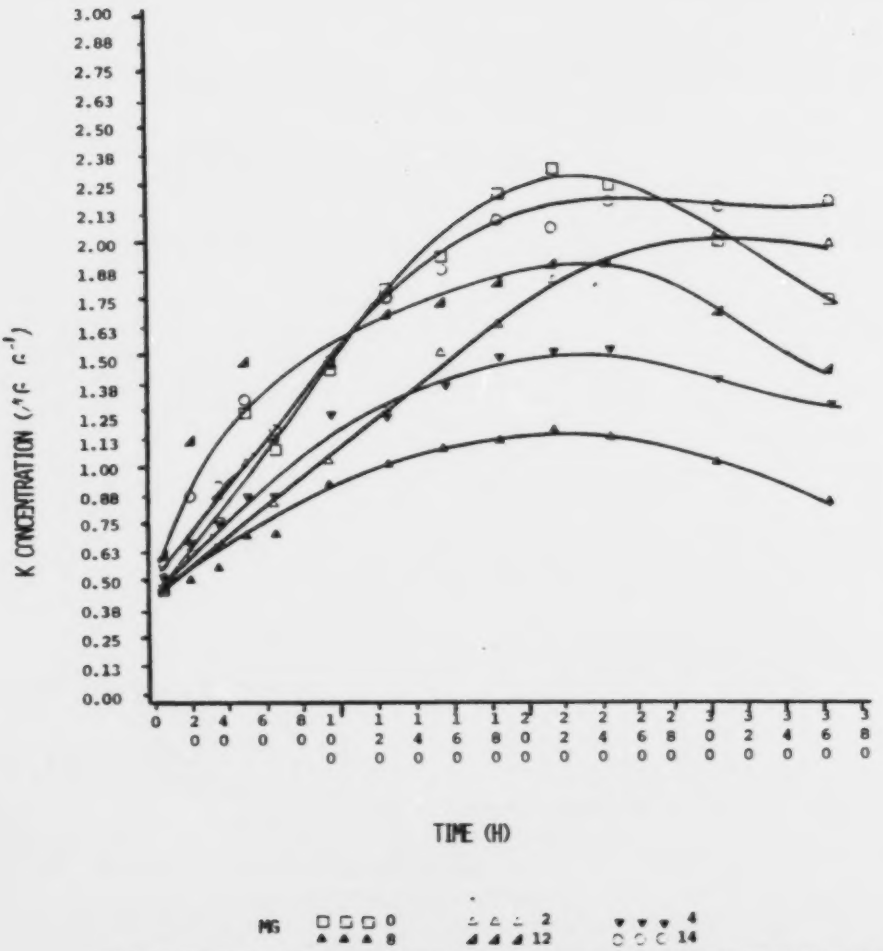

FIG 10: LEAKAGE OF SOLUTES AS INDICATED BY CHANGE IN K CONCENTRATION OF SOLUTION

EFFECT OF ORGANIC MATTER ON CROP YIELDS AND ON SOIL PROPERTIES

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Organic matter has long been recognized as an important soil constituent. As it decomposes it provides essential elements such as nitrogen, phosphorus and sulphur. However, if we are to maintain organic matter at a constant level nutrients provided by decomposing organic matter must of necessity be replaced on a regular basis. Thus, at a constant organic matter level the organic matter cannot be a net source of nutrients for plant growth.

However, organic matter has effects on soil physical properties which influence plant growth. These include soil structure, and hence aeration, as well as the water retention capacity of the soil.

The effect of organic matter on crop yields which is independent of its effect on nutrient supply has received relatively little attention. However, Mattingly reports results of a study in which he compared the effect of three kinds of organic materials on crop yields. These were manure, cereal straw and peat. Manure decomposes readily and is relatively rich in nutrients, the cereal straw also decomposes easily but is highly carbonaceous and tends to immobilize nitrogen during its decomposition, peat is high in nutrients but relatively resistant to decomposition. He reported that where manure was added yields were increased by 10 to 12 percent over and above what could be expected from the nutrients they supplied. Where an adequate nutrient level was maintained little or no yield increase was obtained from the addition of peat or cereal straw over and above that obtained by nutrients alone.

Racz* added an oil sludge to a Red River clay soil at rates which provided 0, 0.12, 0.34 and 0.62% carbon. He found barley yields were enhanced by the addition of this material over and above that which could be obtained from nutrient additions alone. Grain yields were 2850, 3400, 3740 and 3750 Kg per hectare for the 0, 0.12, 0.34 and 0.62% application rates of carbon, respectively. It was postulated that the enhancement of yields due to addition of the sludge resulted from improved soil structure.

In order to assess the effect of organic matter on crop yields a greenhouse experiment was initiated using the Ap horizon of an Orthic Chernozem containing chemical and physical characteristics as shown (Table 1). The study involved the addition of two types of residue which it was felt would decompose rapidly. One was wheat straw containing 0.6 percent N, and the other alfalfa residue containing 3.4 percent N. Both residues were added at 2.5 percent by weight (about one percent carbon) to 5000 Kg of soil in 5.7 litre pots. For comparison pots were included to which no residue was added. The fertility treatments consisted of addition of a single rate of P, K, S, Zn and Cu to all pots as follows: P at 100 ppm as KH_2PO_4; S at 30 ppm as K_2SO_4; Zn at 20 ppm as $ZnSO_4 \cdot 7H_2O$ and Cu at 10 ppm as $CuSO_4 \cdot 5H_2O$. The above treatments provided 200 ppm of K. In addition to the above,

*Unpublished data.

four rates of N were included as follows: where no residue was added and where 2.5 percent of straw was added, rates of nitrogen were at 0, 200, 400 and 600 ppm N as NH_4NO_3. Nitrogen was not all added at one time. The additions were as follows:

At seeding May 29	- 200 ppm to all pots receiving N.
June 10 - straw treated pots	- 200 ppm N to 400 and 600 ppm treatments.
June 26 - no straw pots	- 200 ppm N to 400 and 600 ppm treatments.
June 26 - straw treated pots	- 200 ppm N to 600 treatments.
July 17 - no straw treated	- 200 ppm N to 600 treatments.

Alfalfa residue treated pots did not receive N. Thus there were a total of nine treatments. As there were four replicates the experiment consisted of 36 pots. Conquest barley was the test crop.

The crop was seeded (placing six seeds in each pot) on May 29 and water added to moisten the upper half of the pot. After emergence plants were thinned leaving four plants per pot. After about two weeks, when the crop was up, sufficient water was added to bring the soil to a moisture content of 30 percent by weight, -0.03 mPa.

The plants were grown in a growth chamber with 16 hours light and 8 hours darkness and with day-night temperatures of 22°C and 13°C, respectively. The only exception was the period of 10 days from June 25 to July 4 when, due to a breakdown of the growth chamber, the pots were transferred to a growth bench. Here there was less temperature control and daytime temperatures reached about 30°C.

The crop was harvested on August 23 by cutting the plants off at ground level. The plant material was dried and threshed. Plants were analyzed for nitrogen, phosphorus, potassium, sulphur and several micronutrients. Soils were also analyzed. In October the soils were repotted and a second crop of barley was grown using 4500 g soil with the addition of 50 ppm of P as KH_2PO_4. The crop was harvested as follows:

Treatments	I-III	- Jan. 16/85
	IX	- Jan. 22
	IV, VIII	- Jan. 23
	V	- Jan. 24
	VI, VII	- Jan. 25

March 7 a third crop was grown using 2000 g soil per pot. The treatments were split with all of the pots receiving 30 ppm S as K_2SO_4 - no additional P or micronutrients were added. Half of the pots received 300 ppm N as NH_4NO_3 with 200 ppm being added at planting on March 7 and an additional 100 ppm on April 4. The pots which did not receive N were harvested May 7. The N treated pots were harvested May 13. As before grain and straw were dried, threshed, weighed and samples analyzed.

A second study was undertaken in the summer of 1985. For this study Gretna clay was used. Samples were taken at three locations on land of approximately 10 percent slope, namely, at upper, middle and lower slope positions. These soils ranged from 3.0 to 6.4 percent in organic matter content. There were also major differences in fertility

level, particularly with respect to P and K (Table 1). The experiment consisted of twelve treatments and four replicates each. All pots received basal dressings as follows: K_2HPO_4 - 125 ppm P; K_2SO_4 - 38 ppm S; $ZnSO_4$ - 25 ppm Zn; $CuSO_4$ - 12.5 ppm Cu. The above treatments provided 406 ppm of K. Nitrogen was applied using $^{15}NH_4{}^{15}NO_3$ with ^{15}N enrichments of 5.3% and 5.0% on the NH_4^+ AND NO_3^- radicals, respectively.

The variables used consisted of three soils representing the upper, middle and lower slope positions, two cereal residue treatments - 0 and 2.5 percent by weight, and two nitrogen levels. The nitrogen levels were 150 and 300 ppm where no straw was added and 300 and 600 ppm where straw was added. At planting nitrogen rates up to and including 300 ppm were added as required. For the 600 ppm treatments the addition of the last 300 ppm was made in two increments of 150 ppm each at 4 and 5 weeks after planting. Six seeds of Conquest barley were seeded in each 5.7 litre pot containing 4000 grams of air dry soil. Pots containing straw had an additional 100 grams in total weight. After planting sufficient water was added to moisten about one-half of the soil volume. Watering to this level was continued until the plants were well established. At that time sufficient water was added to bring the soil to a water content represented by -0.03 MPa. Plant number was reduced to four plants per pot by thinning. The plants were grown in a growth chamber with sixteen hours of daylight at 22°C and eight hours dark at 13°C. Because of crowding as the plants grew bigger the pots from replicate one were moved to a second growth chamber. The three replicates kept in the original growth chamber were affected by mildew and by aphids in the later stages of growth. This necessitated application of Milgo 2E for mildew control and of malathion for control of aphids. These treatments provided effective control but nevertheless yields were affected and hence replicate one outyielded the other replicates. This was generally in the range of five to ten percent of total dry plant weight.

Results and Discussion

The yields of grain and straw (Table 2) indicate that without added residue there was a good response to nitrogen. At this rate of application by comparing nitrogen uptake with that of the check it can be calculated that 68.9 percent of the added nitrogen was recovered in the crop. The second increment of nitrogen did not result in a further yield increase but it did result in an increase in nitrogen content of the plant material. The 600 ppm N treatment appeared to depress the yield of grain although there was an increase in N uptake due to a further increase in the nitrogen percentage in the plant material. With both the 400 and 600 ppm N treatments a considerable amount of nitrogen was recovered in the soil as NO3-N after harvest.

Where wheat straw was added without nitrogen, crop growth was very poor. Presumably this was due to immobilization of nitrogen as the plants manifested symptoms of nitrogen deficiency. The yield was much lower than that obtained with the no straw-no N treatment. Where 200 ppm N was added there was a large increase in yield but the yield with this treatment was less than that of N treated pots to which no residue was added. With higher rates of N there was a further increase in yield with yields being considerably in excess of those obtained

where there were comparable N rates but no straw. Where alfalfa residue was added the yield was almost as large as the highest N treatment with wheat straw. In fact at the early growth stage this treatment appeared to result in the best growth. N uptake in the above ground portion of the crop was calculated on the basis of nitrogen content and yield. Recovery of fertilizer N was calculated on the difference in N uptake between the check and N treated pots. The largest percentage recovery of nitrogen in the plant plus that present as nitrate at harvest occurred where no residue was added and 200 or 400 ppm of N were added. The largest total N uptake by the plant, but smaller total recoveries of nitrogen, occurred with wheat straw plus 600 ppm N and the alfalfa residue.

Two more crops were grown using the same soils but without additional N. The yields from the second crop (data not presented) were quite low and ranged from 9 to 40 grams per 4500 g of soil. Yields indicated that treatments III and IV benefitted from residual nitrate and treatment IX continued to release N from the residue added previously. The third crop was even lower with relatively small differences between treatments where no additional nitrogen was added. This indicated that there was very little release or immobilization of nitrogen by this time.

A summary of the data for the three crops (Table 3) indicates that addition of crop residues increased yields by 30 percent as compared to the highest yields obtained where no residue was added. This appeared to be due to improved structure and lower bulk density.

The data for experiment three in the series to which N was added (Table 4) indicate a beneficial effect from the residue treatments added before taking crop 1. There was a tendency for yields to be higher in the treatments which gave the lowest yields in crops 1 and 2, i.e. low N treatments. The reasons for this is not clear. Of more interest is the relationship of yields obtained where pots received straw prior to crop 1 (XIV to XVII) as compared to those obtained where straw had not been added (treatments X to XIII). Average yield for the latter was 31.8 g and for the former 41.2 g. Thus the residual effect of the straw resulted in yield enhancement of 30 percent. This increase is almost identical to that obtained with the first crop after the straw was added. This indicates that the beneficial effects of a large residue addition persist for some time.

Results from the second study with Gretna clay indicate, once again, that the addition of straw enhanced crop yields provided that there was sufficient nitrogen (Table 5). Increase in yield due to organic matter was calculated as a percentage using the following formula:

$$\frac{\text{Yield with 600 Mg N Kg}^{-1}\text{ + straw - yield with 300 Mg N Kg}^{-1}}{\text{Yield with 300 Mg N Kg}^{-1}} \times 100$$

It was found that the lower the organic matter content of the soil the greater the yield increase due to addition of straw. Thus increases for mid slope (3 percent O.M.), upper slope (5.2 percent O.M.) and lower slope (6.4 percent O.M.) were 41.1, 26.4 and 22.7 percent, respectively. In the ealier study with the Darlingford soil containing 5 percent organic matter the yield increase resulting from the addition of straw

was 31 percent for the first crop and 30 percent for the third crop. This indicates that there is an inverse relationship between soil organic matter and the yield increase resulting from the addition of straw to the soil. These data are in agreement with data obtained by Racz (unpublished). Addition of sludge to a Red River clay containing 4.9 percent organic matter increased barley yield by 31 percent.

These results have interesting implications. In Manitoba in recent years fallow area has decreased steadily and farmers have, on the average, maintained fertilizer application rates for the major annual crops at about 25 Kg P_2O_5 per hectare. When seeded on stubble, crops have received an average of 60 Kg N per hectare in recent years. This has resulted in a large increase in the amount of crop residues returned as roots, straw and stubble. The increase in crop residues returned to the soil may be a factor in the high cereal crop yields obtained in recent years.

Table 1. Physical and chemical characteristics of soils.

Soil Name	Field Capacity %	Texture	S	Si %	C	B.D.	pH	N %	O.M. %	P	K	S
										$MgKg^{-1}$		
Darlingford	30.0	C.L.	26	43	31	0.94	7.2	0.30	5.0	20	370	-
Darlingford + 2.5% straw	-	-	-	-	-	0.84		0.32	5.6			
Gretna - upper slope	26.0	C.L.	34	28	37	1.12	7.6	0.28	5.2	21	280	7
Gretna - upper slope + 2.5% straw	30.2	-	-	-	-	0.84		0.29	-			
Gretna - mid slope	27.0	C	13	31	56	1.10	6.8	0.18	3.0	31	254	7
Gretna - mid slope + 2.5% straw	32.6	-	-	-	-	0.94		0.19	-			
Gretna - lower slope	39.4	SiC	7	44	49	0.82	7.6	0.36	6.4	52	700+	6
Gretna - lower slope + 2.5% straw	44.1	-	-	-	-	0.70		0.39	-			

Table 2. Yield of barley (gms per pot) and recovery of N added as NH_4NO_3 and alfalfa residue.

Treatment	Grain	Straw	Total	N Uptake g. per pot	NO_3-N in Soil	N Recovery %	
						Plant	Plant & Soil NO_3
Check	19	28	47	0.403	-	-	-
200 ppm N.	36	42	78	1.092	-	68.9	68.9
400 ppm N	33	43	77	1.297	0.420	44.7	65.2
600 ppm N	28	41	69	1.364	0.794	32.0	58.5
No N - 2.5% straw	3	4	7	0.075	-	-	nil
200 ppm N - 2.5% straw	28	34	62	0.480	-	7.7	7.7
400 ppm N - 2.5% straw	40	44	86	0.951	-	27.4	27.4
600 ppm N - 2.5% straw	46	56	102	1.457	0.108	35.1	38.6
No N - 2.5% alfalfa	40	56	98	1.437	0.041	24.3	25.3

Table 3. Yield of barley from three crops and recovery of added N.

Treatment	Yield - g per 5000 g soil	Relative yield	N recovered g	N recovered %*
No N	144	79	0.613	-
200 N	181	99	1.358	74.5
400 N	183	100	1.839	61.3
600 N	183	100	2.445	61.1
No N - 2.5% straw	132	72	0.539	nil
200 N - 2.5% straw	182	99	0.952	33.9
400 N - 2.5% straw	207	113	1.610	49.8
600 N - 2.5% straw	223	122	2.156	51.4
No N - 2.5% alfalfa	237	130	2.406	42.2

*Calculated from amount taken up over and above that in the check as a percentage of the N added.

Table 4. Yield of crop 3 with the addition of 300 ppm N as NH_4NO_3 (200 ppm at planting March 7 and 100 ppm N on April 4)

No.	Original treatment	Yield - grams/2000 g soil/pot			N uptake g/pot	N recovery %
		Grain	Straw	Total		
X	No N - no straw	18.8	15.9	34.7	0.384	58.0
XI	200 N - no straw	17.8	15.9	33.7	0.395	56.7
XII	400 N - no straw	14.2	15.9	29.9	0.341	51.2
XIII	600 N - no straw	12.9	15.9	28.8	0.387	58.5
XIV	No N - 2.5% straw	25.8	18.1	44.0	0.440	60.0
XV	200 N - 2.5% straw	23.9	18.8	42.6	0.436	59.8
XVI	400 N - 2.5% straw	22.5	18.1	40.6	0.416	51.2
XVII	600 N - 2.5% straw	20.0	17.6	37.6	0.386	49.5
XVIII	2.5% alfalfa	20.9	16.8	37.7	0.429	52.3

In calculation N recovery as % subtracted the N uptake from the 0 N series which was unamended, i.e. 0.036 g.
At the end of the experiment treatments X-XIII had an average of 9.8 ppm N as compared 2.6 ppm for treatments XIV-XVII. Thus the former had an additional 0.014 g. N as NO_3 would add to recovery in amount of $\frac{0.014}{0.600} \times 100 = 2.3\%$.

Table 5. Yield of barley (gms per pot) and recovery of added nitrogen as affected by addition of straw - (Gretna soil).

Soil slope position	N added ppm	Straw added %	Yield - gms			N %	N uptake g/pot	Fert. N recovered % of added	
			Grain	Straw	Total			*	**
Upper	150	None	30.5	39.0	69.5	0.91	0.63	92	72
	300	"	35.8	43.9	79.8	1.24	0.99	76	62
	300	2.5	31.1	48.2	79.3	0.71	0.56	40	34
	600	2.5	41.6	59.2	100.9	1.05	1.06	42	36
Mid	150	None	31.3	37.9	69.2	0.85	0.59	85	67
	300	"	34.0	42.8	76.8	1.35	1.04	81	65
	300	2.5	32.3	49.6	81.9	0.71	0.58	42	36
	600	2.5	49.1	59.4	108.4	1.15	1.25	49	44
Lower	150	None	39.8	59.3	99.1	0.76	0.75	105	72
	300	"	53.5	64.6	118.2	1.02	1.20	91	67
	300	2.5	33.2	57.8	91.1	0.78	0.71	52	40
	600	2.5	65.0	80.0	145.0	1.02	1.48	58	49

*Calculated as follows: $\frac{\text{N in plant} - \text{NO}_3\text{-N decrease in soil}}{\text{Fertilizer N added}} \times 100$

**Based on ^{15}N enrichment.

POTASSIUM FIXATION IN ALMASIPPI SOILS

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Abstract

Potassium fixation was measured for 11 coarse textured Almasippi soils with a range of applied potassium (0 to 1000 $mg.kg^{-1}$). The fixed potassium was measured and hence is defined in this study, by the difference between the amount of applied K and the increase in the extractable K after equlibration, using 1N NH_4OAc as an extractant. At application rates of 50 and 1000 $mg.kg^{-1}$ the fixed potassium varied from 12% to 84% and 12% to 53%, respectively. All soils showed a trend of increasing amounts of fixed potassium with increasing K application rates and exhibit a decreasing percentage fixation. Among the 11 soils tested, 3 profiles were selected based on high, medium and low fixation to study the effect of applied potassium on potassium fixation at different depths. Amount of K fixed in the various depths was comparable to that of surface soils. Results of simple linear regression analyses demonstrated significant correlation of K fixed at the 50 $mg.kg^{-1}$ with exch Ca, % K saturation and CEC of the soil.

Introduction.

Potassium fixation has been studied extensively during the past decade. It now is known that many soils and certain of the clay minerals fix large amounts of potassium when the materials are dried, following the addition of potassium salt. Less information is available concerning the fixation of potassium in the coarse textured soils where the clay content of the soil is relatively small. However, with increased cropping intensities, higher yielding varieties, and greater use of N and P fertilizers, the need for potassium fertilizer in coarse textured is increasing. Field studies (Murage,1984) have shown the need for K fertilization in the coarse textured Almasippi soil association for wheat. With recent experiments in the department of soil science, some Almasippi coarse textured soils were identified as being responsive to the addition of K. None of the studies however have investigated the extent to which coarse textured soil will fix applied potassium. Some evidence that coarse textured soils may possess the ability to fix potassium is reported by Murage (1984).

The main aim of this study was to compare the extent of potassium fixation by 11 representative almasippi coarse textured soils.

Materials and Methods.

Eleven surface soils were selected randomly to represent the Almasippi coarse textured soils. The location and the selected properties of the soils are given in Table 1.

Potassium fixation was measured using additions of 5 ml of KCl solution containing 0, 0.25, 0.50, 1.00, 2.00 and 5.00 mg K to duplicate 5 g samples of soil. The wetted soils were allowed to evaporate until the water content of the soils were about the field capacity. The moist samples were allowed to equlibrate for 3 days at room temperature (about 25°C) followed by drying for 3 days at the same temperature. Potassium was extracted in 100 ml of 1N NH_4OAc shaking for 30 min. on a horizontal shaker, centrifuging at 2000 rpm for 10 min and filtering through a No. 42 Whatman filter paper. Filtrates were used for measuring potassium using atomic absorption spectrophotometer. The fixed potassium was given by

$$K_{fixed} = K_{applied} - (\text{extractable } K_{treated} - \text{extractable } K_{control}).$$

To separate the sands, the selected soil samples were acidified to pH 5.5 and washed with H_2O if carbonates were present, treated with H_2O_2 and washed with H_2O and wetsieved.

Mineralogical analyses on sand fractions (0.1 to 2.00 mm) were carried out by X-ray diffraction using a Phillips X-ray diffractometer with a Co-target. Oriented mounts of the sand fractions were prepared by the procedure of Jackson (1956) and minerals identified by methods given in Brown (1961).

Results and Discussion.

All soils show (Table 2) significant increases in amounts of fixed potassium with increasing K application rates and decreasing percentage fixation with the exception of two soils at the lower levels of application. Similar observations have been made in clay soils and reported by many workers (Attoe, 1948; MacLean and Simon, 1958; Barber, 1979). In general, K fixation values among the different soils studied are highly variable (Table 2). Soils which fixed small and large amounts of K at the lowest level of application; consistantly fixed the similar amounts even at the highest rate of application. Soil STA90 showed exceptionally high fixing capacity among the soils studied.

Among the 11 surface soil samples studied, 3 soil profiles were selected, based on low, medium and high amounts of K fixation, to study the effect of depth of soil on K fixation. In the deepest horizons of the soil profiles, the effect of organic matter on K fixation is minimized. The selected soil properties of the horizons and fixation values are given in Tables 3-8. In the first two profiles (Tables 4 and 6) and in each horizon, the amount of K fixed are comparable to that of surface samples at each level of application. In the low fixing profile, higher amounts of K fixation were observed at the deepest horizon at each level of application. In addition, high amounts of K fixation were observed at the deepest

horizons of all three profiles where the organic matter content was of insignificant amounts. Variability in K Fixation was observed among the horizons of low fixing soil profile (Table 8). For example adjacent horizons of GY5 and GY6 from the above profile showed remarkable difference in amounts of K fixed at the lowest level of K application. The amount fixed was almost 4 times higher at GY6 when compared with GY5.

Sand fractions (0.1 to 2.00 mm) of GY5, GY6 and Haywood soils were prepared to compare the mineralogy of that fraction using X-ray diffraction analyses. The X-ray diffraction pattern (Fig. 1) showed them to consist predominantly of quartz and felspar and to be lacking in any K fixing minerals. The mineralogical data did not account for the difference in K fixed found amoung these soils.

Table 9 shows the K fixation in the fine sand fraction (0.1 to 2.00 mm) of 4 soils, after removing any organic matter and carbonates. Soil GY5, and GY6 are the deepest horizons of the low fixing profile; Haywood and STA94 are the two high fixing profiles of surface and deep horizons. K fixation values at each application rates were very similar regardless of different depths or soils. The observation leads to the conclusion that the sand fractions are partly responsible for the K fixation in the coarse textured soils. In addition, the percentage fixation was decreased throughout with increasing application rates as observed in the whole soil. The amount of K fixation was also increased with the increased application rate with the exception of the highest level of K application, where the amount of fixed potassium was significantly lower than 400 mg^{-1} application rate. The decrease in amount of fixation at the highest level of application in the sand fraction was notably different from the whole soils, where the amount of fixation was increased with the increasing application rates. The amount of K fixation in the sand fractions are somewhat less than the amount fixed in the corresponding whole soils, with the exception of GY5 where the sand fraction fixed somewhat larger amount than the whole soil at the lower levels of application. The fixation values obtained from the different studies are usually not comparable because of the different methods of measurements. Nevertheless the value obtained for the sand fractions at the 1000 $mg.kg^{-1}$ application rate are in agreement with the results observed by MacLean and Brydon (1963).

Simple linear regression analyses of surface soil samples demonstrated (Fig. 2) that a definite positive relationship of K fixed at 50 $mg.kg^{-1}$ with exch Ca ($r^2 = 0.82^{**}$) and CEC ($r^2 = 0.63^{**}$) of the soil and a definite negative relationship with % K saturation ($r^2 = 0.79^{**}$). In addition multiple linear regression analysis relating K fixation at 1000 $mg.kg^{-1}$ application rate with soil characters CEC (me/100 g), % organic carbon, exch K (me/100 g) and exch Ca (me/100 g) gave a highly significant R^2 of 0.94. The equation relating all four factors with K fixation is given by

$$y = 14.25 + 1.14 \text{ CEC} - 6.47 \text{ \% organic.C} - 27.3 \text{ K} + 0.82 \text{ Ca}.$$

There was no relationship found between the amount of fixed potassium and the clay content of the soil. The non relationship between K fixed and the clay content, and the clear relationships with exch Ca and CEC of the soil may be a clue for a different

mechanism of K fixation in coarse textured soils.

From the above study it was clearly evident that coarse textured soils are capable of retaining applied K against 1N NH_4OAc extraction which is believed to be fixed. The quantity of fertilizer K rendered unavailable in this way can be very high. So far the mechanisms responsible for this reactions are not clear. Therefore futher detailed studies are needed to clarify this.

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References

1. Attoe, O.J. 1948. Fixation and recovery by oats of potash applied to soils. Proc. Soil Sci. Soc. Am. 13. 112-115.

2. Barber, R.G. 1979. Potassium fixation in some Kenyan soils. J.Soil Sci. 30, 785-792.

3. Brown, G. 1961. X-ray identification and crystal structures of clay minerals. Mineralogical Society (clay minerals group) London.

4. Jackson, M.L. 1956. Soil chemical analyses. Advanced Course. University of Wisconsin.

5. MacLean, A.J. and Brydon, J.E. 1963. Release and fixation of potassium in different size fractions of some Canadian soils as related to their mineralogy. Can. J. Soil Sci. 43, 123-134.

6. McLean, E.O. and Simon, R.H. 1958. Potassium Status of some Ohio soils as revealed by greenhouse and laboratory studies. Soil Sci. 85, 324-332.

7. Murage, P.M. 1984. Potassium as a limiting nutrient for maximum production of wheat in Manitoba. M.Sc. thesis. Department of Soil Science, University of Manitoba.

Table 1. Selected Properties of the Coarse Textured Surface Soils.

Location*	Soil Series	Soil No.	Texture	% Sand MS	% Sand FS	% Sand VFS	% Silt	% Clay	% Org.C	% $CaCO_3$ equvi.	pH ($CaCl_2$)	Exch.K (me/100g)
Rathwell (NE8-8-8W)	Elm Creek	RWL7	LFS	3.00	68.00	9.00	10.00	10.00	0.42	0.00	7.40	0.50
St.Claude (NW35-8-7W)	Almasippi	SC357	VFSL	14.00	25.00	35.00	11.00	15.00	4.73	7.50	7.60	0.18
Portage LP (SE15-10-7W)	Long Plain	SC315	LS	49.00	30.00	5.00	7.00	6.00	3.47	0.00	7.20	0.10
St.Claude (SE26-7-7W)	St.Claude	SC297	FSL	4.00	26.00	24.00	26.00	20.00	4.86	20.70	7.90	0.20
Steinbach (SE16-6-7E)	Lenswood	STA90	FSL	5.00	50.00	22.00	12.00	10.00	3.21	2.80	7.40	0.10
Gladstone (NW17-13-11W)	Almasippi	WBN66	LFS	4.00	50.00	29.00	7.00	10.00	2.20	9.20	7.80	0.30
Gladstone (SE28-14-12W)	Willowcrest	WBN41	FS	3.00	67.00	21.00	4.00	5.00	1.46	0.00	6.80	0.40
Elm Creek (NW NE1/4 22-8-5W)	Long Plain	GY1	FS	2.00	58.00	31.00	4.00	5.00	0.80	0.00	6.80	0.20
Elm Creek (NW1/4 14-8-5W)	St.Claude	GY14	FS	0.00	22.00	45.00	14.00	19.00	2.50	18.00	8.20	0.35
Barnsley (SE1/4 26-7-5W)	Willocrest	GY50	FS	1.00	43.00	48.00	3.00	5.00	1.60	0.00	7.10	0.36
Brandon (NW7-10-18W)	Stockton	BRA1	FSL	21.00	43.00	13.00	8.00	12.00	2.04	0.00	7.10	0.20

* Nearest town.

Table 2. Influence of Amount of Applied Potassium on Potassium Fixation in Coarse Textured (surface) Soils.

Applied Potassium (mg K per kg soil)	% and amount of potassium fixed (mg K per kg soil)*										
	Soil No.										
	RWL7	SC357	SC315	SC297	STA90	WBN66	WBN41	GY1	GY14	GY50	BRA1
50	(30) 15 a	(66) 33 a	(68) 34 a	(50) 25 a	(84) 42 a	(52) 26 a	(18) 9 a	(12) 6 a	(48) 24 a	(30) 15 a	(38) 19 a
100	(28) 28 ab	(56) 56 a	(46) 46 a	(54) 54 a	(84) 84 b	(51) 51 a	(31) 31 ab	(26) 26 ab	(43) 43 ab	(30) 30 ab	(37) 37 a
200	(23) 46 b	(48) 96 a	(44) 88 b	(52) 104 b	(74) 147 c	(50) 99 ab	(28) 55 bc	(14) 27 ab	(36) 72 b	(22) 44 ab	(37) 73 b
400	(23) 93 c	(48) 192 b	(35) 139 c	(46) 182 c	(69) 274 d	(41) 162 b	(24) 96 c	(13) 50 ab	(30) 121 c	(21) 84 b	(40) 158 c
1000	(19) 191 d	(33) 328 c	(20) 202 d	(33) 326 d	(53) 534 e	(29) 286 c	(14) 136 d	(12) 124 b	(24) 244 d	(18) 175 c	(29) 290 d

* % Fixation given in parentheses.
Values followed by the same letter in any column are not significantly different at the 5% level according to Tukey's Studentized Range Test.

Table 3. Selected Properties of a Soil Profile. (Steinbach (SE16-6-7W) Lenswood Series)

Soil No.	Horizon	Depth (cm)	Texture	% Sand MS	% Sand FS	% Sand VFS	% Silt	% Clay	% Org.C	% $CaCO_3$ equvi.	pH	Exch.K (me/100g)
STA90	Ah	0-14	FSL	5.00	50.00	22.00	12.00	10.00	3.21	2.80	7.40	0.10
STA91	ACagj	14-26	LFS	5.00	57.00	23.00	6.00	8.00	0.43	7.60	7.50	0.16
STA92	AC	26-42	LFS	5.00	66.00	16.00	8.00	6.00	0.26	13.80	7.70	0.14
STA93	Cksj	42-48	FS	4.00	61.00	27.00	4.00	2.00	-	7.30	7.70	0.13
STA94	CKgj	48-76	FS	4.00	43.00	46.00	5.00	2.00	-	6.70	7.70	0.14
STA95	CKgj	76-110	FS	12.00	41.00	40.00	3.00	3.00	-	2.50	7.60	0.13

Table 4. Influence of Amount of Applied Potassium on Potassium Fixation in a Soil Profile (Lenswood Series)

Applied Potassium (mg K per kg soil)	% and amount of potassium fixed (mg K per kg soil)* Soil No. and Depth (cm) STA90 (0-14)	STA91 (14-26)	STA92 (26-42)	STA93 (42-48)	STA94 (48-76)	STA95 (76-110)
50	(84) 42 a	(100) 50 a	(78) 39 a	(96) 48 a	(92) 46 a	(74) 37 a
100	(84) 84 b	(85) 85 a	(73) 73 b	(92) 92 b	(81) 81 b	(79) 79 b
200	(74) 147 c	(80) 159 b	(72) 143 c	(76) 151 c	(69) 137 c	(66) 132 c
400	(69) 274 d	(70) 281 c	(61) 244 d	(52) 206 d	(44) 176 d	(52) 207 d
1000	(53) 534 e	(55) 546 d	(43) 425 e	(28) 282 e	(17) 170 d	(21) 210 d

* % Fixation given in parentheses.
Values followed by the same letter in any column are not significantly different at the 5% level, according to Tukey's Studentized Range Test.

Table 5. Selected Properties of a soil profile. (Gladstone (NW17-13-11W) Almasippi Association)

Soil No.	Horizon	Depth (cm)	Texture	% Sand			% Silt	% Clay	% Org.C	% $CaCO_3$ equvi.	pH	Exch.K (me/100g)
				MS	FS	VFS						
WBN66	Ap	0-15	LFS	4.00	50.00	29.00	7.00	10.00	2.20	9.20	7.80	0.30
WBN67	AC	15-20	FS	4.00	67.00	21.00	4.00	4.00	0.14	4.70	7.80	0.12
WBN68	Ckgj	20-67	FS	5.00	56.00	30.00	3.00	6.00	-	10.40	7.80	0.21
WBN69	Ckg	67-130	FS	6.00	56.00	34.00	2.00	2.00	-	10.90	7.80	0.29

Table 6. Influence of Amount of Applied Potassium on Potassium Fixation in a Soil Profile (Almasippi Association)

Applied Potassium (mg K per kg soil)	% and amount of potassium fixed (mg K per kg soil)* Soil No. and Depth (cm)			
	WBN66 (0-15)	WBN67 (15-20)	WBN68 (20-67)	WBN69 (67-130)
50	(52) 26 a	(64) 32 a	(78) 39 a	(76) 38 a
100	(51) 51 a	(57) 57 ab	(67) 67 b	(65) 65 b
200	(50) 99 ab	(53) 105 bc	(61) 122 c	(53) 106 c
400	(41) 162 b	(39) 155 cd	(41) 164 d	(40) 158 d
1000	(29) 286 c	(21) 207 d	(22) 217 e	(22) 221 e

* % Fixation given in parentheses.
Values followed by the same letter in any column are not significantly different at the 5 % level, according to Tukey's Studentized Range Test

Table 7. Selected Properties of a Soil Profile. (Elm Creek (NW NE¼ 22-8-5W) Long plain Gleyed Regosol)

Soil No.	Horizon	Depth (cm)	Texture	% Sand			% Silt	% Clay	% Org.C	% $CaCO_3$ equvi.	pH	Exch.K (me/100g)
				MS	FS	VFS						
GY1	Ap	0-30	FS	2.00	58.00	31.00	4.00	5.00	0.80	0.00	6.80	0.20
GY2	Aejg	30-60	S	1.00	72.00	22.00	2.00	3.00	0.20	0.00	6.90	0.21
GY3	AB	60-80	S	1.00	59.00	32.00	4.00	4.00	0.30	0.00	7.00	0.18
GY4	Bg	81-100	S	2.00	70.00	19.00	4.00	5.00	0.30	0.00	7.10	0.19
GY5	BC	100-120	LS	2.00	51.00	34.00	6.00	7.00	0.20	0.20	7.10	0.21
GY6	Cg	120+	LS	1.00	51.00	35.00	8.00	5.00	-	0.30	7.30	0.20

Table 8. Influence of Amount of Applied Potassium on Potassium Fixation in a Soil Profile (Long plain Gleyed Regosol)

Applied Potassium (mg K per kg soil)	% and amount of potassium fixed (mg K per kg soil)* Soil No. and Depth (cm)					
	GY1 (0-30)	GY2 (30-60)	GY3 (60-80)	GY4 (81-100)	GY5 (100-120)	GY6 (120+)
50	(12) 6 a	(50) 25 a	(32) 16 a	(16) 8 a	(14) 7 a	(64) 32 a
100	(26) 26 ab	(39) 39 a	(28) 28 a	(17) 17 a	(24) 24 b	(55) 55 a
200	(14) 27 ab	(28) 55 a	(33) 66 ab	(27) 53 b	(34) 68 c	(49) 98 b
400	(13) 50 ab	(13) 53 a	(30) 121 bc	(24) 94 c	(37) 146 d	(45) 178 c
1000	(12) 124 b	(14) 140 b	(17) 173 c	(21) 208 d	(31) 305 e	(32) 317 d

* % Fixation given in parentheses.
Values followed by the same letter in any column are not significantly different at the 5% level, according to Tukey's Studentized Range Test.

Table 9. Influence of Amount of Applied Potassium on Potassium Fixation in Fine Sand Fraction (0.1 to 2.00 mm) After Removing Carbonates and Organic Matter.

Applied Potassium (mg K per kg soil)	% and amount of potassium fixed (mg K per kg soil)* Soil No. and Depth (cm)			
	GY5 (100-120)	GY6 (120+)	Haywood (0-15)	STA94 (48-76)
50	(54) 27 a	(58) 29 a	(68) 34 a	(68) 34 a
100	(55) 55 b	(57) 57 b	(53) 53 ab	(50) 50 b
200	(40) 80 c	(47) 93 c	(41) 81 bc	(44) 88 d
400	(23) 91 c	(31) 122 d	(27) 109 c	(26) 104 e
1000	(6) 56 b	(6) 64 b	(7) 71 b	(6) 61 c

* % Fixation given in parentheses.
Values followed by the same letter in any column are not significantly different at the 5% level, according to Tukey's Studentized Range Test.

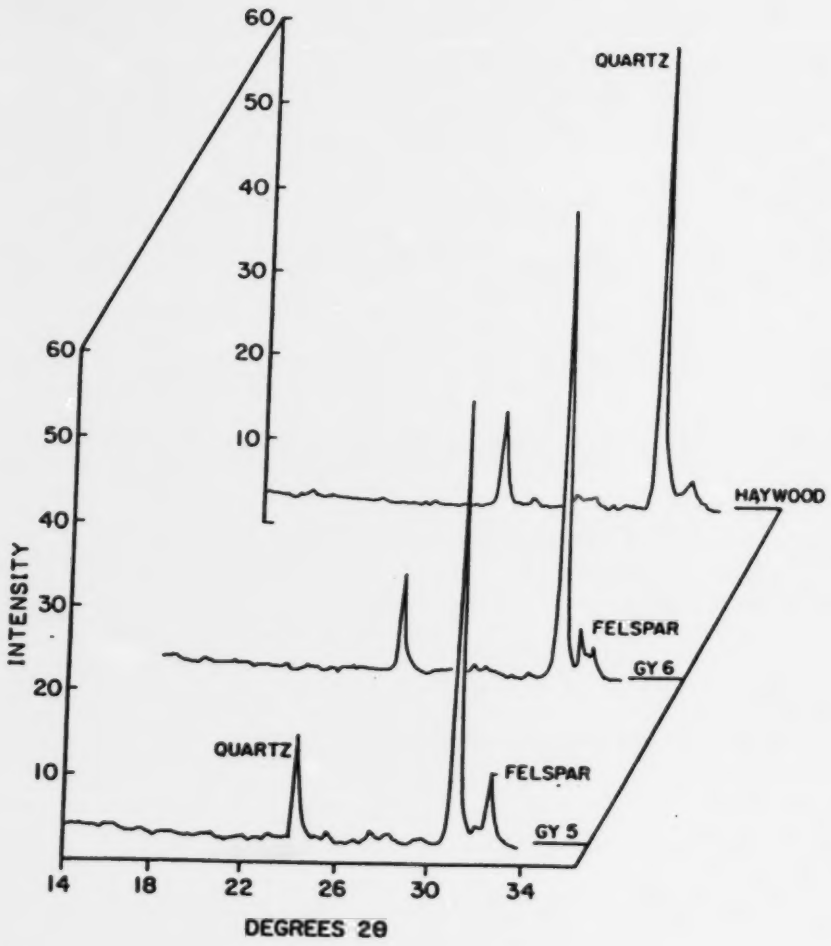
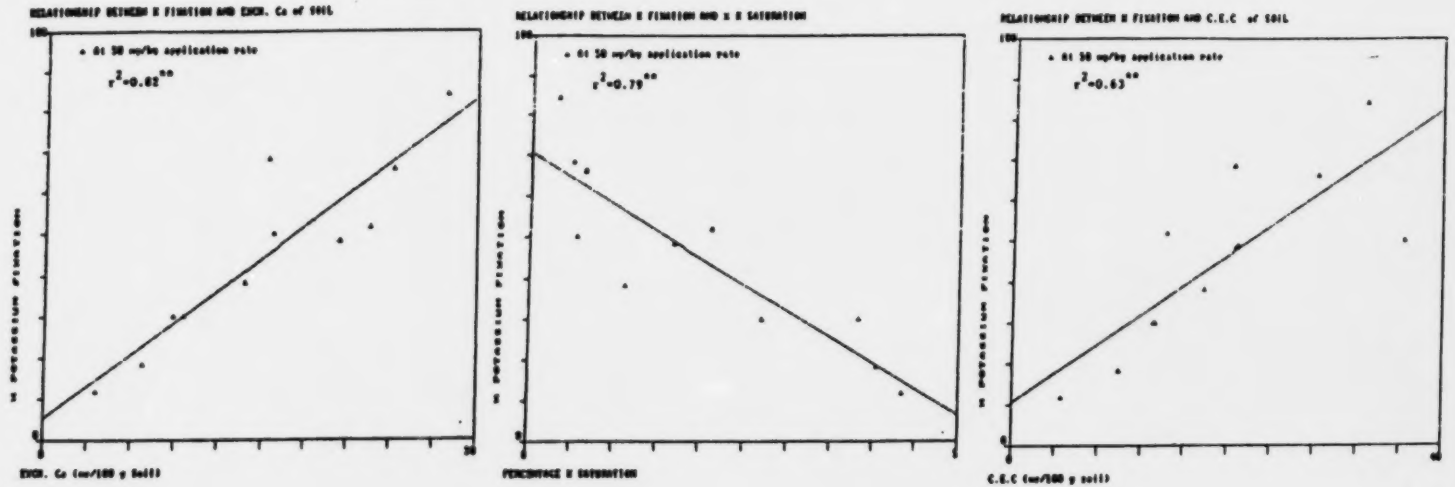


Fig. 1. X-ray diffraction pattern for sand fractions (0.1 to 2.0 mm) of 3 soils (GY5, 100-120 cm; GY6, 120+ cm; Haywood, 0-15 cm).

Fig. 2. Regression relating % potassium fixation at 50 mg per kg application rate to exch.Ca, K saturation and C.E.C of the surface soils.


RELATIONSHIP BETWEEN K FIXATION AND EXCH. Ca of SOIL
at 50 mg/kg application rate
r²=0.82**
% POTASSIUM FIXATION
EXCH. Ca (me/100 g Soil)
RELATIONSHIP BETWEEN K FIXATION AND % K SATURATION
at 50 mg/kg application rate
r²=0.79**
% POTASSIUM FIXATION
PERCENTAGE K SATURATION
RELATIONSHIP BETWEEN K FIXATION AND C.E.C of SOIL
at 50 mg/kg application rate
r²=0.63**
% POTASSIUM FIXATION
C.E.C (me/100 g soil)

THE REGRESSION POLYNOMIAL OF LINE 1 -

(5.411E+00) + (2.581E+00)*X
THE VARIANCE - 7.920E+01

THE REGRESSION POLYNOMIAL OF LINE 1 -

(7.049E+01) + (-1.281E+01)*X
THE VARIANCE - 9.568E+01

THE REGRESSION POLYNOMIAL OF LINE 1 -

(1.065E+01) + (1.789E+00)*X
THE VARIANCE - 1.632E+02

WATER USE EFFICIENCY BY WHEAT AND BARLEY ON THE CANADIAN PRAIRIES FOR THE PERIOD 1958-1984.

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It is a matter of record that wheat and barley yields have been increasing rather rapidly in recent years (Hedlin, 1982). This has been due to several factors including variety improvement and practices such as increased fertilizer use and improved weed control. The increase in crop yields are of such magnitude that they cannot be explained by more favorable weather conditions although this could have been a factor. Therefore one is led to ask whether, and to what extent, there has been an increase in efficiency in the use of water by crops as a result of improved technology. de Jong (1980) concluded that there had been no increase in water use efficiency by wheat in Saskatchewan for the period 1920 to 1969. This is probably true for the time period involved, particularly since his calculations were based on water use and yield by decades rather than individual years.

This study was undertaken in order to ascertain whether there has been a change in water use efficiency when calculations are based on yield and precipitation data for individual years from 1958 to 1984. Precipitation data by crop districts was obtained from the Canadian Wheat Board. It was felt that precipitation for the period September 1 to August 31 best represented the water available to the crop each year. Therefore, precipitation by crop districts for this 12-month period was used to calculate an average figure for each year for each of the three prairie provinces.

The yield data used were obtained from Statistics Canada (Field Crop Reporting Series). This publication contains yields of wheat and barley on fallow and stubble land and also the percentage of each crop seeded on fallow and stubble each year. Crop yields were expressed, not on a seeded area basis but with a correction for fallow percentage using the formula

$$\frac{100}{100 + \text{per cent seeded on fallow}} \times \text{yield per seeded hectare}$$

The resulting figure is referred to as the yield per land hectare.

From the yield and precipitation data grain production per land hectare per cm of water was calculated. Using these data the trend of water use efficiency versus years was calculated. Results for 1958 and 1984 are presented (Table 1). It will be observed that in the case of wheat in 1958, 14.9 to 18.3 Kg of grain per hectare were produced for cm of precipitation. By 1982 this had reached 28.8 to 32.8 Kg per hectare per cm of precipitation. In the case of barley the values were 18.2 to 24.7 Kg per hectare per cm of water in 1958 and 46.6 to 50.7 in 1984.

The data for wheat in Saskatchewan is presented graphically (Fig. 1). It will be observed that most of the data points fall fairly close to the line of best fit. Notable exceptions are 1974 and 1977. In 1974 in both Saskatchewan and Manitoba the spring was wet resulting in delayed seeding. After seeding the weather was hot and dry and

therefore the crop was poor even though the rainfall for the 12-month period September 1, 1973 to August 31, 1974 was high. In 1977 a good crop was obtained from a small amount of precipitation. This was because the fall of 1976 and the winter of 1976-77 was very dry. In 1977 timely rains during and after seeding resulted in a good crop in spite of the low total amount of precipitation from September 1, 1976 to August 31, 1977.

This increase in water use efficiency is in very good agreement with the increase in crop yields (Hedlin, 1982) when both are presented as a percentage change over time (Table 2).

It is not difficult to identify the factors which have been responsible for increased efficiency in the use of water. They include:

1. Variety improvement - inasmuch as variety improvement results in higher yields it contributes to greater water use efficiency. Where variety improvement results in a reduced time to maturity without a decrease in yield it has a similar effect.

2. Improved weed control - a reduction in use of water by weeds results in an increase in water available to the crop.

3. Fertilizer use - by increasing the amount of plant growth application of fertilizers to provide an adequate nutrient supply increases yield and water use efficiency.

4. Decrease in the amount of crop grown on fallowed land. This results in a large increase in the yield per land hectare and in water use efficiency, particularly in the more humid portion of the prairies, provided good weed control practices are followed and adequate fertilizer is used. Under such circumstances yield of crop on stubble land is usually 85 per cent or more than it is on fallow. At such a yield level water use efficiency is increased by 70 per cent or more.

References

1. de Jong, E. and D.R. Cameron. 1980. Efficiency of water use by agriculture dryland crop production. Prairie Production Symposium. Sponsored by Advisory Committee to the Canadian Wheat Board.

2. Hedlin, R.A. 1982. A review of recent crop yield trends. Manitoba Agronomists' Conf. Proc. pp. 85-95.

3. Statistics Canada. Annual Pub. Area and yield of major crops sown on summerfallow and stubble, prairie provinces. Field Crop Reporting Series - No. 1. Cat. No. 22-002.

Table 1. Change in water use efficiency calculated from yield per land hectare and yearly precipitation (September 1 to August 31) for the 27-year period 1958 to 1984.

Province	Crop	Yield of grain Kg/ha/cm.		r
		1958	1984	
Manitoba	Wheat	14.9	32.8	0.74
Saskatchewan	Wheat	18.3	28.8	0.68
Alberta	Wheat	17.5	30.6	0.78
Manitoba	Barley	18.2	48.6	0.82
Saskatchewan	Barley	24.5	46.6	0.78
Alberta	Barley	24.7	50.7	0.88

Table 2. Increase in wheat and barley yields (1958 to 1982) and increase in efficiency of water use (1958 to 1984).

Province	Crop	Inc. in yield %	Inc. in water use efficiency %
Manitoba	Wheat	80.7	120.1
Saskatchewan	Wheat	56.2	57.4
Alberta	Wheat	74.1	74.9
Manitoba	Barley	126.6	167.0
Saskatchewan	Barley	75.1	90.2
Alberta	Barley	112.6	105.3

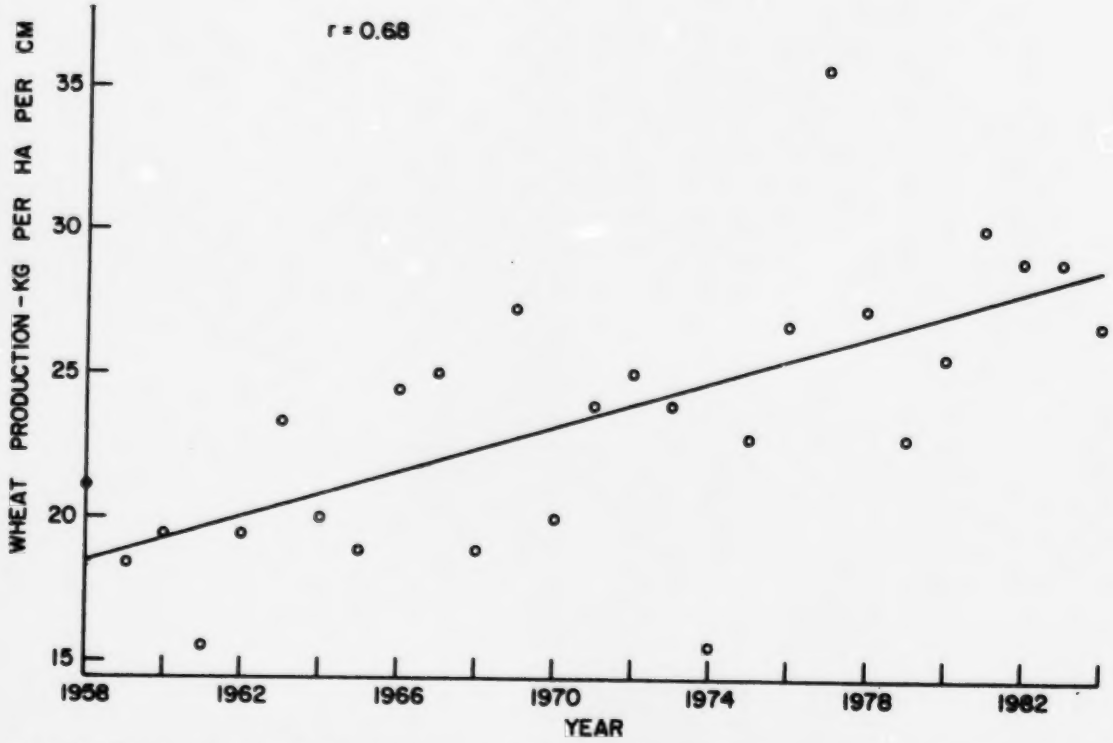

Figure 1 Wheat produced in Saskatchewan in kg per hectare per cm of precipitation for the years 1958 to 1984.

IMPACT OF EFFLUENT IRRIGATION ON SOIL FERTILITY
THE ROBLIN, MANITOBA CASE STUDY

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BACKGROUND

After three years of field study the investigation of various aspects of irrigation using treated municipal effluent conducted near Roblin, Manitoba, has been concluded in the fall of 1984 and the final report completed in 1985.

The project was financed under the Canada-Manitoba Subsidiary Agreement on Value-Added Crop Production as Agro-Man Project 410.

The objectives of the study were to investigate the potential of effluent irrigation in Manitoba's conditions, the possible health risks of such practice, the benefits in hay production and possible environmental impacts, especially on the soil and groundwater, but in this report only the soil fertility related aspects are discussed.

MONITORING PROGRAM

Soil samples for chemical analysis were taken from the irrigated site twice during each year of the study: prior to the start of the seasonal irrigation and after irrigation had ceased for the season. Samples were collected from five different depth levels to a depth of 1.5 metres at each of the six monitoring sites. The sampling depths or "Horizons", were as follows: Horizon 1: 0 cm - 15 cm; Horizon 2: 15 cm - 30 cm; Horizon 3: 30 cm - 60 cm; Horizon 4: 60 cm - 100 cm; Horizon 5: 100 cm - 150 cm. Each sample was replicated three times on each occasion. Sampling was done by randomly choosing three locations at each of the six monitoring sites each time samples were collected.

A computer aided statistical analysis of the data was performed using an analysis of variance procedure of the SAS package to determine the significance of changes indicated in the data.

Major Nutrients

The soil samples were analysed to determine available nitrogen, phosphorus, potassium and sulphur in the soil of the irrigated site. The farmer cooperator had not added any additional commercial fertilizer during the time period of the study. The addition of an annual application of phosphorus to the soil would probably have increased measured yields and improved the quality of the forage stand.

Available nitrogen in the soil remained relatively constant throughout the study, ranging from 2.4 ppm to 19.4 ppm in the top four horizons and 0.7 ppm to 1.4 ppm in the lowest horizon. It was generally considered that nitrogen was available in sufficient amounts to

adequately support the production of the alfalfa-bromegrass. No abnormal behavior in nitrogen concentrations was observed as a result of the effluent irrigation.

Phosphorus concentrations measured in the soil samples were typical of those found in soils with similar cropping history. Measured concentrations decreased during the course of the study from an initial level of approximately 30 ppm to a level of approximately 7 ppm. Increased production of the alfalfa-bromegrass would have been realized with an annual application of 35 kg/ha of phosphorus fertilizer.

Concentrations of potassium measured in the soil samples declined moderately throughout the study from initial levels of 410 ppm to 210 ppm by the end of the study. Available potassium in the soil was sufficient for the production.

The sulphur concentrations of the soil increased as a result of irrigation using municipal effluent. Concentrations increased at all sampled depths from original levels of approximately 3.7 ppm to final levels of 19.1^{+} ppm. The rate of increase had later slowed down and sulphur levels seem to be beginning to stablize. Concentrations of this magnitude pose no current problems to production. Soil test based fertilizer use recommendations did not indicate a need for any additional sulphur fertilizer to increase production. It is probable that the effluent is supplying the sulphur requirements of the production as well as increasing the concentration of sulphur in the soil.

Sodium Adsorption Ratio

Analysis of the soil samples taken from the irrigated site also included the determination of the sodium adsorption ratio. Connected with this analysis was the determination of the soil pH, conductivity, and of the concentrations of sodium, calcium and magnesium respectively.

It was found that soil pH had exhibited erratic behavior throughout the study. Generally, however, it increased during the first two years of the study and then decreased in the final year. An overview of measured soil pH in Horizon 1 is shown in Table 1. Initial soil pH was measured at 7.2. It reached a maximum of to 8.1 in September of 1983 and then decreased to 7.1 in September of 1984. The optimum range of soil pH required by alfalfa is usually defined as 6.2 to 7.8.

TABLE 1. Soil pH in the depth from 0 cm to 15 cm.

Date	pH
82 Spring	7.2
82 Fall	7.4
83 Spring	7.8
83 Fall	8.1
84 Spring	7.5
84 Fall	7.1

The measured conductivity of soil exhibited behavior very similar to that of the soil pH, initially increasing and then decreasing in the final year in the upper horizons. The conductivity of the lower horizons continued to increase even during 1984.

Seasonal effect was also noted in the upper horizons where measured values of conductivity tended to be higher at the time of the fall sampling as compared to those measured in the samples taken in the spring. The conductivity of the Horizon 1, as shown in Table 2, has risen from 0.13 mmhos/cm measured initially to 0.74 mmhos/cm measured in the fall of 1984. Values as high as 1.1 mmhos/cm have been measured twice in the course of the study. The lower horizons showed a similar trend except that the magnitude of the changes and the measured values themselves were considerably smaller.

TABLE 2. Soil conductivity in the depth from 0 cm to 15 cm.

Date	Conductivity mhos/cm
82 Spring	0.13
82 Fall	1.11
83 Spring	0.85
83 Fall	1.11
84 Spring	0.59
84 Fall	0.74

Soil sodium concentrations increased throughout the period of the study. Once again concentrations measured tended to be higher in samples taken during fall samplings as compared to those of the spring samples. Final concentrations of sodium in the soil ranged from 22 ppm in the lower horizons to 105 ppm in the upper horizons.

Concentrations of calcium measured in the soil samples have changed erratically throughout the study. In general, however, concentrations of calcium have increased since the initiation of irrigation. They also seemed to have seasonal behavior patterns. The magnitude of the increase or decrease of the concentration of calcium in the soil was very large on several occasions. Concentrations decreased during 1984 and their final values were between 60 ppm to 121 ppm at the various horizons.

Concentrations of soil magnesium have increased throughout the period of the study. The increase in magnesium concentrations of Horizon 1 through Horizon 3 have exhibited strong seasonal trends with concentrations measured being highest at the time of the fall sampling each year. Concentrations in Horizon 4 and Horizon 5 have generally increased throughout the period of the study and magnesium appears to be accumulating there.

The sodium adsorption ratio of the soil has also increased as a result of the effluent irrigation. Measured values show also a seasonal effect akin to that of soil pH and conductivity. Table 3 shows the changes in the SAR of the soil in horizons 1, 3, and 5 throughout

the period of the study. The SAR of the upper horizons increased to a maximum of 3.2 during the early part of the study and remained high. The SAR of the lowest horizon increased only slightly throughout the study to current levels of 0.7. An increase of SAR in the lower horizons will most likely continue till they reach a level similar to the SAR of the upper horizons.

TABLE 3. Soil sodium adsorption ratio (SAR) at three depths.

Date	Sodium Adsorption Ratio		
	0 cm-15 cm	30 cm-60 cm	100 cm-150 cm
82 Fall	3.2	0.8	0.5
83 Spring	2.3	0.7	0.3
83 Fall	2.7	1.4	0.6
84 Spring	2.5	1.8	0.6
84 Fall	3.2	1.7	0.7

Micronutrients

The concentrations of manganese, copper, zinc, iron and boron were also monitored.

There has been no dramatic increase or decrease in the concentration of these micronutrients as a result of the effluent irrigation. Soil manganese concentrations have decreased in the upper horizons and increased in the lower horizons. No substantial increase has occurred even though the effluent applied is considered to contain high concentrations of manganese. Concentrations of copper in the soil have shown only slight increases and it is unlikely that any larger increases will occur due to the relatively low concentrations of copper in the effluent.

Concentrations of boron in the soil have fluctuated throughout the period of the study. The concentrations measured at the time of the final soil sampling are not significantly different from the concentrations measured when irrigation was initiated. Samples taken in June of 1984, however, were found to contain significantly higher concentrations of boron than had been measured previously or that were measured at subsequent samplings. This increase in measured concentrations of boron followed the period of a poor second-cut production of 1983 (caused by a delay of the first cut) where no appreciable yield of alfalfa was produced. It is speculated that the lack of an appreciable stand of alfalfa contributed to this increase in soil boron concentrations as boron that normally would have been removed from the soil by the plant uptake of a vigorous alfalfa stand was still present in soil at the time of sampling in the spring of 1984. Boron is present in the effluent in moderately high concentrations but does not seem to have accumulated in the soil under effluent irrigation. Currently it poses no production problems.

Other and General

No other aspects of the soil chemistry monitoring indicated any alarming changes and trends.

Concerns about adverse impact of effluent irrigation on some physical properties of the soil, especially on the soil water-intake rate did not materialize and the physical properties remained unchanged.

CONCLUSIONS

Effluent irrigation resulted in a 120% average seasonal increase in the yield of hay.

The overall conclusions of the study are that, if properly and carefully managed, irrigation using treated municipal effluent in conditions similar to those of the experimental site is safe and beneficial, but that periodical monitoring of the soil properties is even more important than under regular irrigation or in non-irrigated productions.

REFERENCES

Penkava, F.F. and G.B. Murray. 1985. Roblin Effluent Irrigation Study - Final Report. Prepared for the Manitoba Department of Agriculture under the auspices of the Canada-Manitoba Value-Added Crops Production Agreement. 55 p.

EFFECT OF NITROGEN SUPPLY ON YIELD AND PROTEIN CONTENT OF WINTER WHEAT UNDER ZERO TILLAGE AND SPRING WHEAT UNDER ZERO AND CONVENTIONAL TILLAGE

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Introduction

Interest in the production of winter wheat on the Canadian Prairies has increased in recent years because of the potentially high yields and moisture use efficiency of this crop. Winter wheat production has not been feasible until recently due to low winter survival of present varieties under conventional till management. However, under zero till management, whereby previous crop stubble is left standing to trap snow/insulate crop, winter wheat survival has been improved and production made possible.

High yields of winter wheat, however, are not likely to be achieved without the application of fertilizers, particularly nitrogen. Since winter wheat is a new crop on the eastern prairies, little information is available on crop response to added nitrogen.

Zero tillage has improved soil conservation on the prairies and by snow trapping, has increased moisture retention. Therefore, spring wheat produced under zero till manangement may require a higher nitrogen rate to achieve a higher production potential.

The project reported herein is a three year study initiated in the fall of 1984 to study (1) production of winter wheat under zero tillage compared to spring wheat under zero and conventional tillage; and, (2) to determine the effect of nitrogen on yields and protein content of spring and winter wheat. Results reported are from the first crop year of a three year study.

Materials and Methods

The experiment was established on two soil types in the fall of 1984: Manitou C.L. near Manitou and Wellwood V.F.S.C.L. near Carberry. Winter wheat at the Carberry site did not survive the winter, thus only data from the Manitou site is presented.

The experimental design consisted of three main blocks: (1) winter wheat zero tilled (WWOT); (2) spring wheat zero tilled (SWOT); and, spring wheat conventionally tilled (SWCT). Main blocks where not randomized. Randomized, blocked and replicated (six times) subplot treatments consisted of incremented rates of nitrogen from 10 to 300 kg/ha.

Winter wheat (c. Norstar) was sown September 7, 1984 into standing barley stubble. Spring wheat (c. Neepawa) was sown May 7, 1985 into both standing barley stubble and conventionally tilled

land. Conventional tillage consisted of one fall deep (10.0 cm) tillage and harrowing and one spring tandem discing (7.5 cm deep) and harrowing. All wheat was sown 4.0 cm deep at a rate of 110 kg/ha using a Versatile-Noble Model 2200 hoe press drill. This drill has 10 hoe-openers 19.6 cm apart.

Subplot treatments consisted of 10 rows each 10 M long. All treatments received 25 kg P/ha applied with the seed using 11-51-0. Nitrogen as urea (46-0-0) was applied surface-broadcast, post-seeding. All wheat was sprayed for weed control as required. In addition, winter wheat was sprayed twice with fungicide (TILT) for disease control.

At harvest, 4 rows by 2 metres long were hand-cut by sickle at ground level; bagged, air-dried, thrashed and weighed for yield measurement. Treatment yields were adjusted to 13.5% moisture content. Samples of each treatment were ground and analyzed on a micro kjeldhal unit for crude N. Protein was calculated:
% Protein = 5.7 x % N (and adjusted to 13.5% moisture content).

Results and Discussion

Winter wheat was planted into very dry soil in the fall of 1984. However, approximately 4 cm of rain occurred 2 days later and the crop germinated and emerged uniformly. The crop was in the 3-4 leaf stage at freeze-up. Spring wheat was planted into moist soil and it too germinated and emerged uniformly. Condition during the growing season were cool but moist and the crops grew prolifically and yielded highly.

Winter and spring wheat were inspected for disease. Common root rot, rust, take-all and tan spot were identified in the winter wheat. The infections occurred in patches throughout the crop, thus the effect on yield was not measured. Little evidence of disease was apparent in the spring wheat.

Soil analysis conducted on samples taken in the fall of 1984 showed that the plot site soil was low in nitrate nitrogen, medium in extractable phosphorus and very high in sulfate sulfur (Table 1). Crop response to added nitrogen could be expected.

The effect of nitrogen fertilizer on yields of winter and spring wheat are shown in Table 2, and plotted lines of best fit are shown in Figure 1. Wheat yields were high for both winter and spring wheat. Range of yields were 2952 to 5225 kg/ha WWOT; 3475 to 4724 kg/ha SWOT; and, 2991 to 4683 kg/ha SWCT. Highest yields of WWOT, SWOT, and SWCT occurred at 240, 180, and 300 kg N/ha respectively. However, lines of best fit (Fig. 1) show highest yields for SWOT and SWCT occurred at 240 kg N/ha. Lowest yields of each wheat/tillage type occurred at the lowest N rate. Figure 1 shows that each wheat/tillage type models the typical nitrogen-yield response curve, for levels of N used in this experiment. That is wheat yields increase with low N, level off at optimum N, and decrease at excess N. Mean yields for the wheat/tillage types are not significantly different, likely due to the high growing season rainfall and that winter wheat and zero tillage management require drier conditions

to demonstrate their yield advantages. However, trends in the data are apparent. Firstly, at the 10 kg N/ha rate SWOT outyielded SWCT, but was virtually the same thereafter. Secondly, WWOT yielded less than SWOT and about equal to SWCT at 10 and 30 kg N/ha, but yielded somewhat greater at 240 kg N/ha. This is indicative of the high yield potential of WWOT and the high nitrogen requirement to realize that yield potential. It is noteworthy to add that lodging at high N rates, and plant diseases were experienced to a much greater degree by winter than spring wheat. This may well have prevented winter wheat from realizing even greater yields and a significant difference from spring wheat.

The effect of nitrogen fertilizer on protein contents of winter and spring wheat are shown in Table 3, and plotted lines of best fit are shown in Figure 2. The range of protein contents was 9.0 to 11.5% for WWOT; 11.7 to 15.0% for SWOT; and, 11.6 to 14.8% for SWCT. Protein content was low for each wheat/tillage type at the low N rate and increased as the N rate increased. This is a the typical nitrogen-protein content response curve. Protein contents of SWOT and SWCT were almost identical, however, WWOT protein contents are substantially lower and significantly different from spring wheat even at high rates of N. This denotes the genetic difference between these wheat varieties (cultivars used). However, also noteworthy is that the amount of increase of protein content is not significantly different betwen varieties.

Yield and protein content data, when examined together, show that with adequate nitrogen fertilizer, both high yield and high protein content can be achieved simultaneously; by winter wheat under zero tillage, and spring wheat under zero and conventional tillage.

Table 1. Characteristics of soil at the Manitou site in 1984-85

Depth (cm)	pH	Conductivity (seimens/m)	OM (%)	Total N (%)	NO_3-N (kg/ha)	Ext. P (ppm)	K (ppm)	SO_4-S (kg/ha)
0-15	7.0	0.037	5.4	0.24	8.64	11.8	363	6.5
15-60	-	-	-	-	11.52	-	-	578
TOTAL	-	-	-	-	20.16	-	-	574.5

Table 2. Effect of nitrogen rate on grain yields of winter and spring wheat at the Manitou site 1985.

Treatment			Yield (@ 13.5% of Moisture)					
			Winter Wheat Zero Tilled		Spring Wheat Zero Tilled		Spring Wheat Conventional Tilled	
No.	N kg/ha	P[1] kg/ha	kg/ha	Grouping[2]	kg/ha	Grouping[2]	kg/ha	Grouping[2]
1	10	25	2952	d	3475	d	2991	b
2	30	25	3440	d	3767	cd	--	-
3	60	25	4167	c	4187	bc	4108	a
4	90	25	4397	bc	4463	ab	--	-
5	120	25	4734	abc	4261	ab	--	-
6	180	25	4605	abc	4724	a	4536	a
7	240	25	5225	a	4444	ab	--	-
8	300	25	5145	ab	4612	ab	4683	a

[1]25 kg/ha of P = 57 kg/ha of P_2O_5
[2]treatment means in same column followed by same letter are not significant by different (alpha = .05) by Duncan's MRT.
[3]mean of treatments 1,3,6,8 by wheat/tillage type:

4217	a	4250	a	4080	a

Table 3. Effect of nitrogen rate on grain protein contents of winter and spring wheat at the Manitou site 1985.

Treatment			Protein Content[2]					
	N	P[1]	Winter Wheat Zero Tilled		Spring Wheat Zero Tilled		Spring Wheat Conventional Tilled	
No.	kg/ha	kg/ha	(%)	Grouping[3]	%	Grouping[3]	(%)	Grouping[3]
1	10	25	9.3	b	11.7	c	11.6	b
2	30	25	9.0	b	11.7	c	--	
3	60	25	9.7	b	12.0	c	11.9	b
4	90	25	9.5	b	13.8	b	--	
5	120	25	10.0	b	14.2	ab	--	
6	180	25	11.4	a	14.6	ab	14.8	a
7	240	25	11.3	a	14.8	a	--	
8	300	25	11.5	a	15.0	a	14.8	a

[1]25 kg/ha of P = 57 kg/ha of P_2O_5

[2]total N of grain x 5.7 and adjusted to 13.5% moisture

[3]treatment means in same column followed by same letter are not significantly different (alpha = .05) by Duncan's MRT

[4]mean of treatments 1,3,6,8 by wheat/tillage type: 10.5 b 13.3 a 13.2 a

[5]amount of increase of protein over range: 2.5 a 3.3 a 3.2 a

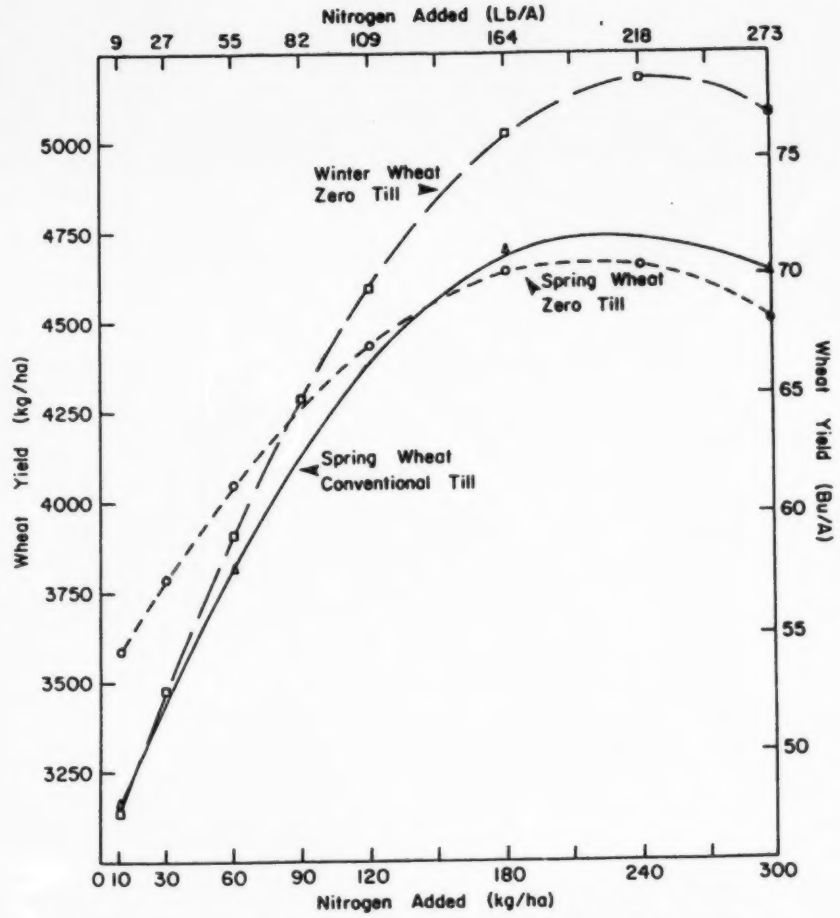

Figure 1. Effect of Nitrogen on Yields of Winter and Spring Wheat. (Lines of Best Fit)

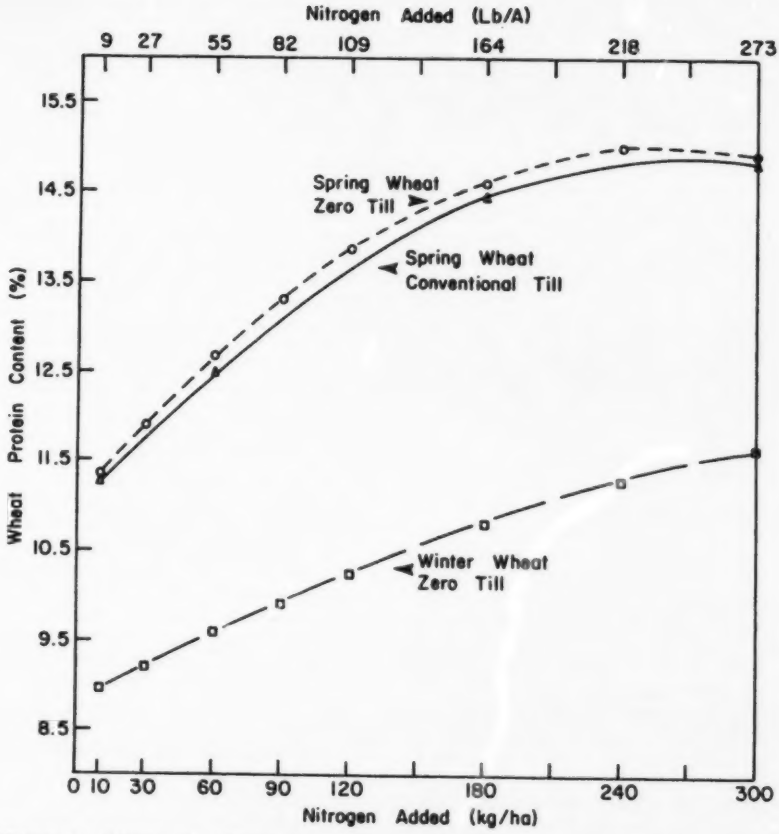

Figure 2. Effect of Nitrogen on Protein Contents of Winter and Spring Wheat. (Lines of Best Fit)

HERBICIDE RESIDUES IN MANITOBA STREAM WATERS AND SEDIMENTS - OBSERVATIONS AND PREDICTIONS

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INTRODUCTION

Movement of pesticides from agricultural land to stream waters has been studied extensively in Ontario (Harris and Miles, 1975; Frank and Sirons, 1979; Frank et al. 1982), Quebec (Muir et al. 1978), the U.S. East coast (Goltfelty et al. 1984; Correll et al. 1978) and the mid-west corn belt (Richard et al. 1975; Schnoor et al. 1982). These studies have related herbicide use and cropping practices in each watershed to the residues in stream waters. There appears to have been no similar effort to relate herbicide contamination of Canadian or northern U.S. prairie streams to quantities used in the watersheds or to land use practices. Monitoring surveys by the Water Quality Branch (Inland Waters Directorate, Environment Canada) for pesticides in Western Canadian rivers include determination of the herbicides 2,4-D, 2,4-DB, 2,4,5-T, dichlorprop, fenoprop and picloram (Environment Canada, 1985). With the exception of 2,4-D and picloram these herbicides are not used in Western Canada. WQB sampling sites are generally located near interprovincial or international boundaries making it difficult to relate residues to herbicide use above the sampling point because of the large size of most watersheds involved and the lack of data on quantities and land use practices.

Large quantities of herbicides are used for weed control in the three prairie provinces (Smith, 1982). For example 654,000 kg of 2,4-D, 579,000 kg of MCPA and approximately 2×10^6 kg of various "wild oat" herbicides (mainly dichlofop-methyl, triallate, trifluralin and bromoxynil) were used in Manitoba in 1979 (Smith, 1982). The fate of most of these compounds in current use has been studied extensively in soils under prairie conditions (Smith, 1982) and mass balance studies of several compounds applied under field conditions have been conducted (Grover et al. 1985). The pathways by which herbicides reach stream waters are well known for humid Eastern Canadian and U.S. conditions but are less well characterized for the drier conditions of the prairies. For example, runoff events shortly after herbicide applications have been shown to be major contributors to total loading of atrazine in Ontario streams (Frank et al. 1979) but there frequently will be no storm runoff events in prairie streams during the growing season with major overland flows and erosion occurring only during spring snow melt. Inputs from aerial deposition and from spraying activities (e.g., washing equipment) in the watershed may be more important contributors to herbicide loading under prairie conditions (Grover et al. 1985).

This study was initiated in collaboration with the Fish Resource and Development Section of DFO Western Region which is conducting a Walleye (Stizostedion vetreum) fishery rehabilitation program in Dauphin

Lake in west central Manitoba (Flannagan et al. 1985). As part of the project the Ochre River was studied extensively for its suitability as a spawning stream for Walleye. In addition to information on stream biology, data were available on river flow rates, land use practices and herbicide use for the Ochre and other rivers in the Dauphin Lake watershed. The opportunity was therefore presented to survey herbicide residues in selected stream waters and to relate the results to various watershed characteristics. For comparison with the Ochre River which drains predominately non-cropped land and forest (Riding Mountain National Park) except near the sampling site (Fig. 1) we chose the Turtle River which drains mainly agricultural lands at the south end of Dauphin Lake. A sampling program was conducted with the objective of monitoring residues of the major herbicides used in each watershed in stream flow during 1984.

METHODS

Sampling procedures. Sampling sites were located on the Ochre River south of the town of Ochre River and on the Turtle River at the highway 5 bridge north of the town of McCreary, Manitoba (Fig. 1). Water samples were collected in 4L amber glass solvent bottles (prewashed with acetone and hexane) by holding the bottle just below the water surface until filled. Collections were made on March 14, April 13, April 27, and at weekly intervals thereafter until Sept. 5/84. A final collection was made on Oct. 10/84. All collections were made in duplicate, 100 mL of dichloromethane (DCM) was added immediately and the bottles were capped with Teflon screw caps. Samples were refrigerated (4°C) except during transport to Winnipeg (6 hrs).

Analysis. The method used for extraction of the neutral and acid herbicides from water samples was a modification of the procedures used by Birkholtz and Schwanbeck (1985). The objective was to recover both acid and neutral herbicides from a large acidified sample then methylate a portion of the extract so that acid herbicides could be determined by gas chromatography (GC). Analytical procedures are described in more detail by Muir and Grift (1986).

Gas chromatographic analysis. A Varian 6000 GC equipped with an ^{63}Ni-electron-capture detector and a Model 4270 integrator was used for all analyses. Extracts were chromatographed on a 30 m x 0.25 mm o.d. DB-5 fused silica capillary column using nitrogen carrier gas (80 Kpa) temperature programmed from 70°C (2 min hold) to 250° at 15°C/min with an 8 min hold at the higher temperature. Under these conditions GC retention times ranged from 10.7 min for trifluralin to 20.6 min for diclofop-methyl. Quantitation was performed by use of external standard mixtures of neutral herbicides and of the methyl esters of acid herbicides. Detection limits based on a minimum peak area of 500 counts (about 0.2 cm peak height) ranged from 2 to 10 ng/L for most of the compounds with 2 L samples.

GC-Mass spectrometry was carried out on a HP 5987 instrument in the electron-impact mode. Pooled sample extracts (8 L equivalents from each stream) were chromatographed on a 60 m x 0.25 mm o.d. DB-5 column using He carrier gas. Spectra were acquired in the scanning mode (m/e 50-550). Extracted ion chromatograms were obtained at m/e 264, 306, and 335 for trifluralin, m/e 86, 267 and 270 for triallate, m/e 127 128, 277, 278 for bromoxynil octanoate, and m/e 253, 281, 340, 342 for diclofop-methyl.

Herbicide and land use. Surveys of herbicide use conducted by the Manitoba Crop Insurance Corp. (M.C.I.C.) were obtained for the Dauphin Lake region (Crop Zone 6). Data on total insured area of major crops (wheat, oats, barley, alfalfa, rapeseed and flax) and the quantity of herbicide applied to them were available on a municipality basis. The municipalities of Ochre River and McCreary were selected because their borders coincided well with the area of the watersheds being monitored. Land use characteristics for each watershed were obtained from the Remote-Sensing Office of the Manitoba Dept. of Natural Resources. The proportion of each watershed in cropped land, grassland, deciduous and coniferous forest, or urban was available from Landsat images.

RESULTS AND DISCUSSION.

Herbicide use in each watershed. Herbicide surveys by M.C.I.C. for 1982 were available when planning for the 1984 monitoring program was underway. Subsequently surveys for 1983 became available (Table 1). In all three years major herbicides in both watersheds were dicamba, diclofop-methyl and MCPA. Bromoxynil, difenzoquat, 2,4-D (amine salt), triallate, trifluralin and propanil were applied in smaller amounts. Of these compounds difenzoquat (a diphenyl pyrazolium salt), propanil and MCPA could not be readily determined with existing analytical methodology. MCPA could be recovered along with other phenoxyacid herbicides but having 1 chlorine it had much lower detection limits than the others (Cessan et al. 1985). Actual quantities of each herbicide used in each watershed were estimated by the following procedure: Comparison of the insured cropland from the M.C.I.C. survey and the cropped area from the Landsat survey indicated that about 10% of the land in each municipality was covered by the herbicide survey. We assumed that the survey was representative of actual use in each watershed and obtained total use of each herbicide by multiplying quantities used by the ratio of cropped land to insured land. The resulting quantities may be relatively accurate for herbicides used exclusively on agricultural land, for example in the control of wild oats, but may underestimate use of products such as 2,4-D which are used for broadleaf control in pastures and for brush control on non-agricultural land. Pasture lands accounted for 39% and 44% of agricultural land area in the Ochre and Turtle River watersheds, respectively.

Herbicide residues in river water. Triallate and trifluralin were the only herbicides detected in neutral water extracts. Concentrations of the two herbicides never exceeded 25 ng/L in all samples analysed (Fig. 2). Detectable levels of triallate were found during April, May and June and again in September and October in both rivers. Trifluralin followed a similar pattern although it was found at detectable levels on only 3 occasions in Ochre River water and was close to detection limits (<3 and <5 ng/L) in almost all samples from the Turtle River (Fig. 2). The presence of triallate and trifluralin in Turtle River water extracts was confirmed on a pooled sample (4 samples from May) by GC-MS.

Triallate and trifluralin concentrations appeared to have no relationship to runoff or rainfall events because several increases in river flow did not result in increased concentrations of the herbicides. This result contrasts with atrazine losses from Eastern

Canadian and U.S. agricultural watersheds where increased herbicide concentrations are observed with increased flow (Frank and Sirons, 1979; Muir et al. 1978; Golfelty et al. 1984). Williamson (1984) reported concentrations of triallate in LaSalle River waters correlated well (r^2=0.713) with river flow. However, this relationship held true for spring snow melt (April) but not during a period of increased flow in June. The study by Williamson (1984) appears to be one of the few published reports on losses of triallate and trifluralin from agricultural watersheds although the related thiocarbamate herbicide EPTC was monitored in 11 Ontario watersheds (Frank et al. 1982). Williamson (1984) reported triallate and trifluralin residues were present in the LaSalle and Assiniboine River waters especially in April and in November (1983). Triallate concentrations reached 150 ng/L in the LaSalle River during spring snow melt. These results suggest that runoff of fall applied triallate and trifluralin during spring snow melt may account for most losses of these herbicides from prairie agricultural watersheds. In the present study, however, there was little spring runoff observed in 1984 (see flow rates in Fig. 2) and this may explain why high concentrations of the neutral herbicides used in each watershed were not observed.

Dicamba, 2,4-D 2,4,5-T, bromoxynil and diclofop were identified in methylated acid extracts. Unlike the results with neutral herbicides the two rivers differed considerably in the pattern of residues over time (Fig. 3 and 4). In the Ochre River the highest levels of 2,4-D (450 ng/L) were found in mid-April associated with snow melt. In the Turtle River levels of 2,4-D were undetectable (<10 ng/L) during May and most of June while dicamba levels ranged from 20-40 ng/L, just above detection limits (10 ng/L). High concentrations of dicamba and 2,4-D were found in the Turtle River on a single sampling day in late June (Fig. 3) and were readily detected for the next 3 weeks. The high levels of these two herbicides were observed during a period of low water flow (although a major rainfall event occurred 3 days after sampling) suggesting that the levels were due to spray contamination rather than runoff. Further evidence for spray contamination was that 2,4,5-T concentrations did not increase during that week but did increase briefly following the rainfall event (Fig. 4). 2,4,5-T has not been soil in Manitoba since 1980, however, due to past wide use especially for brush control and to persistence in soil and water (Smith, 1982), its presence in water was unexpected. The finding of dicamba and 2,4-D residues together suggests direct contamination of the waterway with one of several formulations in which the two herbicides are combined. Bromoxynil and diclofop were observed in the Turtle River on the sampling date following the major runoff event (Fig. 5) but only at very low levels at other times. Both these compounds were widely used in the watershed and their presence in water as the free phenol (bromoxynil) and acid (diclofop) suggests runoff of the degraded compounds (originally applied as the octanoate ether and methyl ester, respectively). Williamson (1984) reported detection of diclofop at trace (<100 ng/L) levels at two sites on the LaSalle River in 1983. The presence of bromoxynil in river water has not been previously reported although runoff of the compound from treated plots has been studied (Brown et al. 1985).

Dicamba and 2,4-D have been previously observed in surface waters draining agricultural watersheds (Frank et al. 1982; Williamson, 1984). 2,4-D and 2,4,5-T have been frequently reported in Western Canadian

rivers in surveys by the Water Quality Branch of Inland Waters Directorate (Gummer, 1979; Environment Canada, 1985) at similar concentrations to those in this study. Williamson (1984) observed dicamba at trace levels in only 3 of 30 samples from the LaSalle River. Dicamba was not observed (<10 ng/L) during the time of normal spray application (May and June). By contrast, 2,4-D was found in 70% of LaSalle River samples at levels ranging from <10 to 130 ng/L with highest levels found during spring snow melt (Williamson, 1984). Frank and Sirons (1980) observed 2,4-D, dicamba and 2,4,5-T in stream waters from 11 Ontario watersheds although only 7% of samples contained 2,4-D and only 0.1% contained dicamba over a 2-year period. Losses of 2,4-D, dicamba and 2,4,5-T were attributed mainly to spills, drift and direct application to ditches during a two-year period (Frank et al. 1982) with minor contributions due to storm runoff.

Use/Loss ratios. Discharge of herbicides (g/month) from each watershed were approximated by multiplying average flow (m^3/s) by average concentrations of each herbicide. Discharges of all herbicides were highest in May, June and October (Table 2). On a unit-loading basis (mg/ha year) losses of dicamba, 2,4-D and 2,4,5-T were in a similar range to those observed by Frank et al. (1982) in eleven Ontario watersheds. Losses of dicamba and 2,4-D were much higher in the Turtle than Ochre watersheds because of the high concentrations of thes herbicides apparently caused by direct spray contamination. Unit loading of the acid herbicides on the Ochre River and of bromoxynil and diclofop in the Turtle River is probably more representative of the contribution from agricultural uses of these compounds. Losses of triallate were similar in both the Ochre and Turtle watersheds (Table 2) and higher than that observed for the related thiocarbamate EPTC in the study by Frank et al. (1982). Discharges of 2,4,5-T occurred almost entirely in the March to June period suggesting an association with high water flows rather than with use in the watersheds.

CONCLUSIONS

(1) Levels of the herbicides detected in the Ochre and Turtle Rivers were generally in the low ng/L range. Residues were observed either in spring snow melt samples (April) or during periods of normal agricultural use in June and September/October. The low levels of triallate and trifluralin which were clearly unrelated to river flow are suggestive of aerial deposition of sprays or dust to which the herbicides are adsorbed. Aerial inputs have been showen to be an important path of input of herbicides to surface waters in a Saskatchewan watershed study (Grover et al. 1985).

(2) Major residues of diclofop-methyl and bromoxynil occurred only in June following a major runoff event. Only the hydrolysed forms of these two compounds were detected in river waters. This was presumably because of the rapid degradation of both these compounds in soils under field conditions although they may also degrade rapidly in runoff waters.

(3) Based on the available toxicity data for the herbicides monitored in this study the levels of herbicides in the river water would not be expected to have a deliterious effect on fish or fish food organisms. Levels of trifluralin were well below the suggested MATC (maximum

acceptable toxicant concentration) of 1.9 µg/L. Bromoxynil, which has similar toxicity to some species of fish as trifluralin (WSSA, 1983) would be expected to have a similar MATC. On this basis the levels of bromoxynil in the Turtle River would have reached about 10% of the acceptable level for fish for a brief period. The wide use of this compound suggests that its appearance in river water should be investigated more thoroughly. The high levels of dicamba and 2,4-D observed in June are still well below IJC water quality objectives for 2,4-D of 400 µg/L (Frank and Sirons, 1980).

REFERENCES

Birkholtz, D.A. and L. Schwanbeck. 1985. LaSalle River study analytical report. Environ. Protect. Service, Environ. Canada, Edmonton. 31 pp.

Brown, D.F., D.K. McCool, R.I. Papendick and L.M. McDonough. 1985. Herbicide residues from winter wheat fields: Effect of tillage and crop management. J. Environ. Qual. 14, 521-532.

Cessna, A.J., R. Gover, L.A. Kerr and M.L. Aldred. 1985. A multiresidue method for the analysis and verification of several herbicides in water. J. Agric. Food Chem. 33, 504-507.

Correll, D.L., J.W. Pierce and T.L. Wu. 1978. Studies of the transport of atrazine and alachlor from minimum till corn fields into Chesapeake Bay tidal waters. Proc. Northeast. Weed Sci. Soc. 32, 21-32.

Environment Canada. 1985. Detailed Surface Water Quality Data. Alberta, Manitoba, Northwest Territories and Saskatchewan, 1982. Inland Waters Directorate, Regina. 278 pp.

Flannagan, J.F., J.A. Mathias and W.G. Franzin, 1985. Fisheries rehabilitation research - the Dauphin lake walleye rehabilitation pilot project. Unpublished project. Dept. of Fisheries and Oceans, Winnipeg.

Frank, R., H.E. Braun, M. Van Holdrinet, G.J. Sirons and B.D. Ripley. 1982. Agricultural and water quality in the Canadian Great Lakes Basin: V. Pesticide use in 11 agricultural watersheds and presence in stream water, 1975-77. J. Environ. Qual. 11, 497-505.

Frank, R. and G.J. Sirons. 1980. Chlorophenoxy and chlorobenzoic acid herbicides: Their use in eleven agricultural watersheds and their loss to stream waters in southern Ontario, Canada 1975-77. Sci. Total Environ. 15, 149-167.

Golfelty, D.E., A.W. Taylor, A.R. Isensee, J. Jersey and S. Glenn. 1984. Atrazine and simazine movement to the Wye river estuary. J. Agric. Food Chem. 13, 115-121.

Grover, R., S.R. Shewchuk, A.J. Cessna, A.E. Smith and J.H. Hunter. 1985. Fate of 2,4-D iso-octyl ester after application to a wheat field. J. Environ. Qual. 14, 203-210.

Grover, R., L. Kerr, D. Waite and H. Sommerstad. 1985. Transport of herbicides in a small agricultural watershed. A preliminary report. Presented at the Plains Aquatic research Conference, Univ. of Regina, Regina.

Gummer, W.D. 1979. Pesticide monitoring in the prairies of Western Canada. In: Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment, B.K. Afghan and D. Mackay, Eds. Plenum Press, N.Y. 588 pp.

Harris, C.R. and J.R.W. Miles. 1975. Pesticide residues in the Great Lakes region of Canada. Residue Rev. 57, 27-79.

Muir, D.C.G., J.Y. Yoo and B.E. Baker. 1978. Residues of atrazine and deethylated atrazine in water from five agricultural watersheds in Quebec. Arch. Environ. Contam. Toxicol. 7, 221-235.

Muir, D.C.G. and N.P. Grift. 1986. Herbicide residues in two Manitoba agricultural watersheds. Final report to EPS, Edmonton, Jan. 1986.

Richard, J.J., G.A. Junk, M.J. Avery, N.L. Nehring, J.S. Fritz and H.J. Svec. 1975. Analysis of various Iowa waters for selected pesticides: atrazine, DDE and dieldrin - 1974. Pestic. Monit. J. 9, 117-123.

Schnoor, J.L., N.B. Rao, K.J. Artwright and R.M. Noll. 1982. Fate and transport modeling for toxic substances. In: Modeling the Fate of Chemicals in the Aquatic Envoronment, Dickson, K.L., Maki, A.W. and J. Cairns Jr. (Eds.), Ann Arbor Science, pp. 145-163.

Smith, A.E. 1982. Herbicides and the soil environment in Canada. Can. J. Soil Sci. 62, 433-460.

Weed Science Society of America (WSSA). 1983. Herbicide Handbook, 5th Ed. Champaign, Ill. 515 pp.

Williamson, D.A. 1984. A preliminary inmvestigation into the presence of agricultural pesticides in the La Salle and Assiniboine Rivers, Manitoba, Canada. Manitob Dept. of Environ., Water Standards and Studies Rpt. No. 84-5. 37pp.

Table 1. Quantities of herbicides used in Ochre and Turtle river watersheds - 1982-83

Herbicide	Quantity (kg) on each major crop (insured land only)										Total on insured land		Total in watershed[2]	
	wheat		barley/oats/rye		flax		rapeseed		miscellaneous[1]					
	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983
OCHRE RIVER														
bromoxynil	88	61	26	14	39	32	-	-	-	-	153	107	1662	1680
2,4-D[3]	0	52	0	97	-	-	-	-	-	-	0	149	-	2340
diclofop-methyl	431	235	258	141	-	-	29	29	-	-	818	405	8885	6360
difenzoquat	0	34	-	-	-	-	-	-	-	-	0	34	-	534
dicamba	148	149	32	0	-	-	-	-	-	-	180	149	1965	2340
MCPA	173	73	474	17	99	33	24	0	-	-	770	123	8364	1931
triallate	35	0	35	0	72	0	30	0	-	-	172	0	1868	-
trifluralin	-	-	-	-	25	-	69	58	17	0	136	58	1477	910
triazines[4]	-	-	-	-	-	-	-	-	158	146	158	146	1205	2292
propanil	18	0	61	0	32	0	-	-	-	-	101	0	1096	-
TURTLE RIVER														
bromoxynil	271	33	37	0	160	32	73	0	-	-	541	55	3880	879
2,4-D	218	146	0	41	-	-	-	-	-	-	218	187	1563	2530
diclofop-methyl	205	221	-	-	128	-	265	122	-	-	598	343	4288	4638
difenzoquat	83	47	-	-	-	-	-	-	-	-	83	47	595	635
dicamba	104	67	-	-	-	-	-	-	-	-	104	67	746	906
MCPA	173	369	212	161	85	33	-	-	-	-	470	563	3370	7613
triallate	109	0	-	-	-	-	24	0	-	-	133	0	954	-
trifluralin	-	-	-	-	-	-	368	71	-	-	368	71	2640	960
propanil	74	48	0	63	-	-	-	-	-	-	74	111	531	1501
asulam	-	-	-	-	59	55	-	-	-	-	59	55	423	743

1- corn, alfalfa, bromgrass.

2- obtained by multiplying ratio of cropped land to insured cropland by quantity used on insured land. Ratios were 10.86 in 1982 and 15.7 in 1983 on the Ochre River and 7.17 in 1982 and 13.5 in 1983 for the Turtle River watershed.

3- quantities of 2,4-D likely underestimated due to use for brush control.

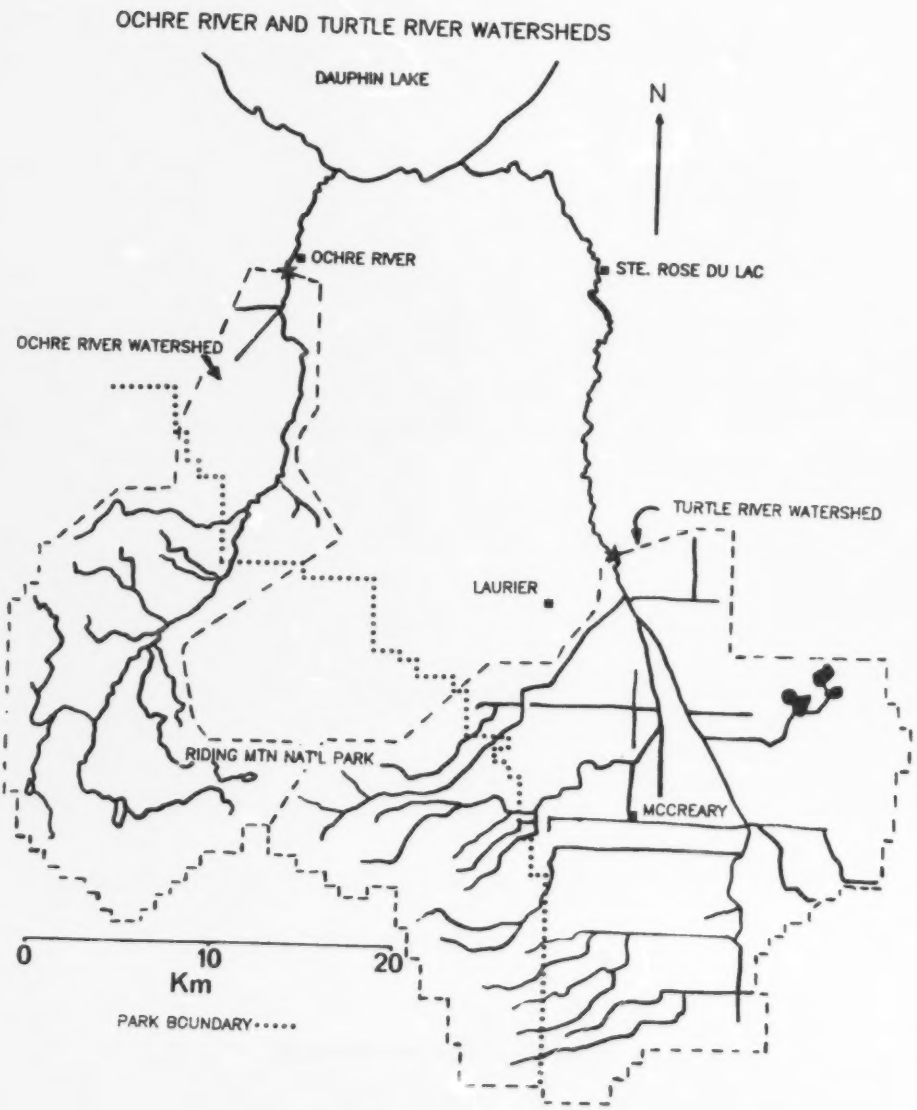
4- mainly atrazine.

Table 2. Herbicide discharge (g/month) from the Ochre and Turtle Rivers (1984).

Month	Mean Discharge (m^3/sec)	Average herbicide concentration (ug/m^3)							Estimated herbicide discharge (g/month)[1]						
		triflur-alin	triallate	dicamba	2,4-D	2,4,5-T	bromoxy-nil	diclofop	triflur-alin	triallate	dicamba	2,4-D	2,4,5-T	bromoxy-nil	diclofop
OCHRE RIVER															
April	1.70	<1.3	2.4	9.7	227	30.9	<0.5	3.4	<5.7	10.6	42.7	999.5	136.1	<2.2	15.0
May	4.19	3.3	0.6	22.2	13.3	14.8	0.24	<3	37.0	6.7	249.1	149.2	166.1	2.7	<33.7
June	2.61	<0.6	0.4	48.4	21.6	12.2	1.63	2.9	<4.1	2.7	327.2	146.0	82.5	11.0	19.6
July	0.376	<0.6	<0.7	14.0	4.5	3.8	0.7	1.2	<0.6	<0.7	14.1	4.5	3.8	0.7	1.2
August	0.030	<0.6	<0.7	31.6	5.4	3.9	0.7	<2.5	<0.05	<0.06	2.5	0.4	0.3	0.1	<0.2
Sept.	0.030	<0.6	<0.7	31.6	5.4	3.9	0.7	<2.5	<0.05	<0.06	2.5	0.4	0.3	0.1	<0.2
October	0.892	22.9	6.4	17.6	<11.5	3.8	<1.0	<12.5	81.8	22.9	62.8	<41.1	13.6	<3.6	<44.6
Total discharge (g/year)									119	43	698	1300	402	15	36
TURTLE RIVER															
March	0.72	<2.5	<2.8	105.1	49.1	60.6	<1.0	<12.5	<4.8	<5.4	202.6	94.7	116.8	<1.9	<24.1
April	2.10	<2.5	<2.8	103.1	32.0	20.2	<1.0	<12.5	<13.6	<15.4	560.8	174.0	109.9	<5.4	<68.0
May	2.40	1.2	10.4	29.0	2.3	3.7	0.3	1.4	8.0	66.8	186.4	14.8	23.8	1.9	9.0
June	4.59	0.6	9.9	1737	830	<0.6	32.3	124.7	7.1	117.7	20650	9867	<7.1	384.0	1482
July	0.44	0.6	2.7	234	23.1	6.6	37.2	5.4	0.7	3.2	275.7	27.2	7.8	43.8	6.4
August	0.053	<0.5	<0.5	86.3	11.0	4.1	0.4	<2.5	<0.07	<0.07	12.2	1.6	0.6	0.1	<0.4
Sept.	0.192	<2.5	3.7	19.3	13.8	7.2	1.0	<12.5	<1.2	1.8	9.6	6.9	3.6	0.5	<6.2
October	1.52	5.2	5.5	104.1	38.2	<2.4	0.3	<12.5	21.2	22.4	423.7	155.5	<9.8	1.2	<50.9
Total discharge (g/year)									37	212	22321	10342	263	432	1497

1- Avg. water conc (mg/m^3) X total monthly flow (m^3).

Figure 1. Map of the Ochre and Turtle River watersheds.



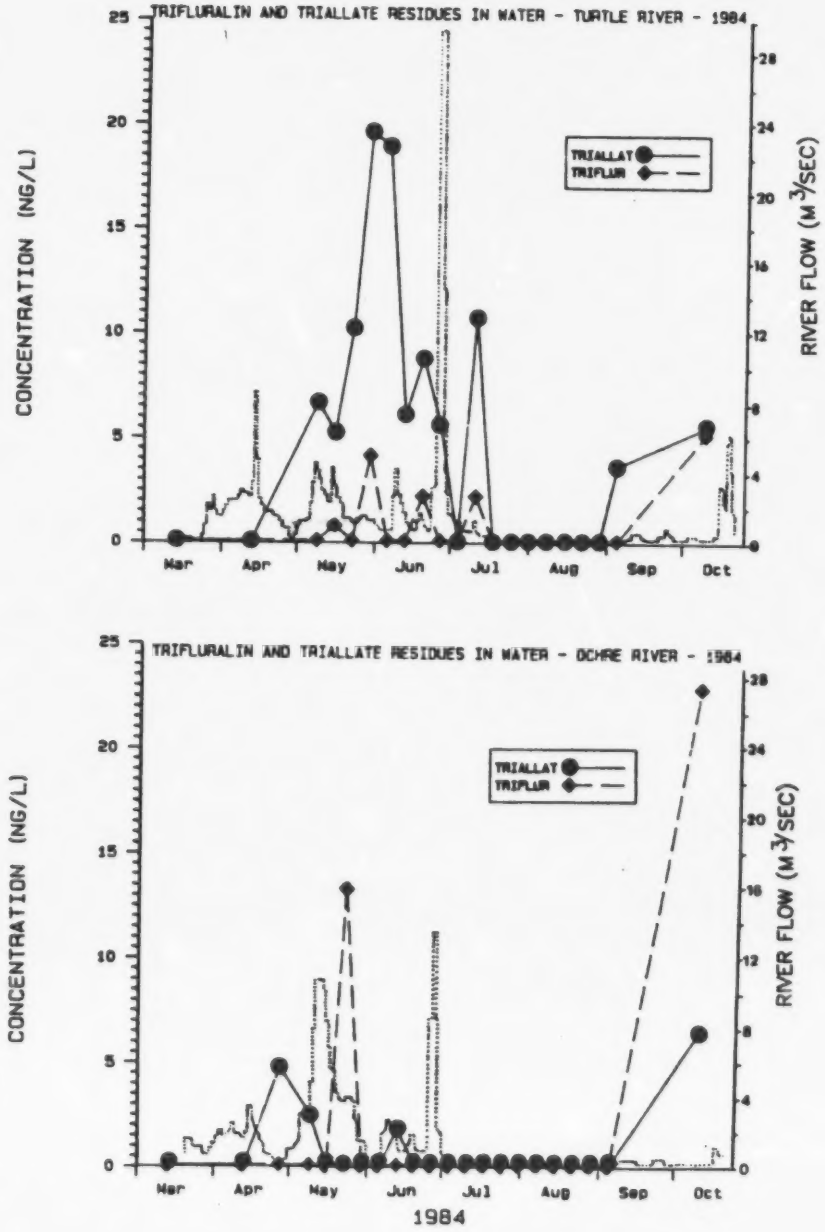


Figure 2. Triallate and trifluralin concentrations (ng/L) and river flow (m^3/sec) in the Ochre and Turtle Rivers during 1984. River flow is indicated by the continuous dotted lines.

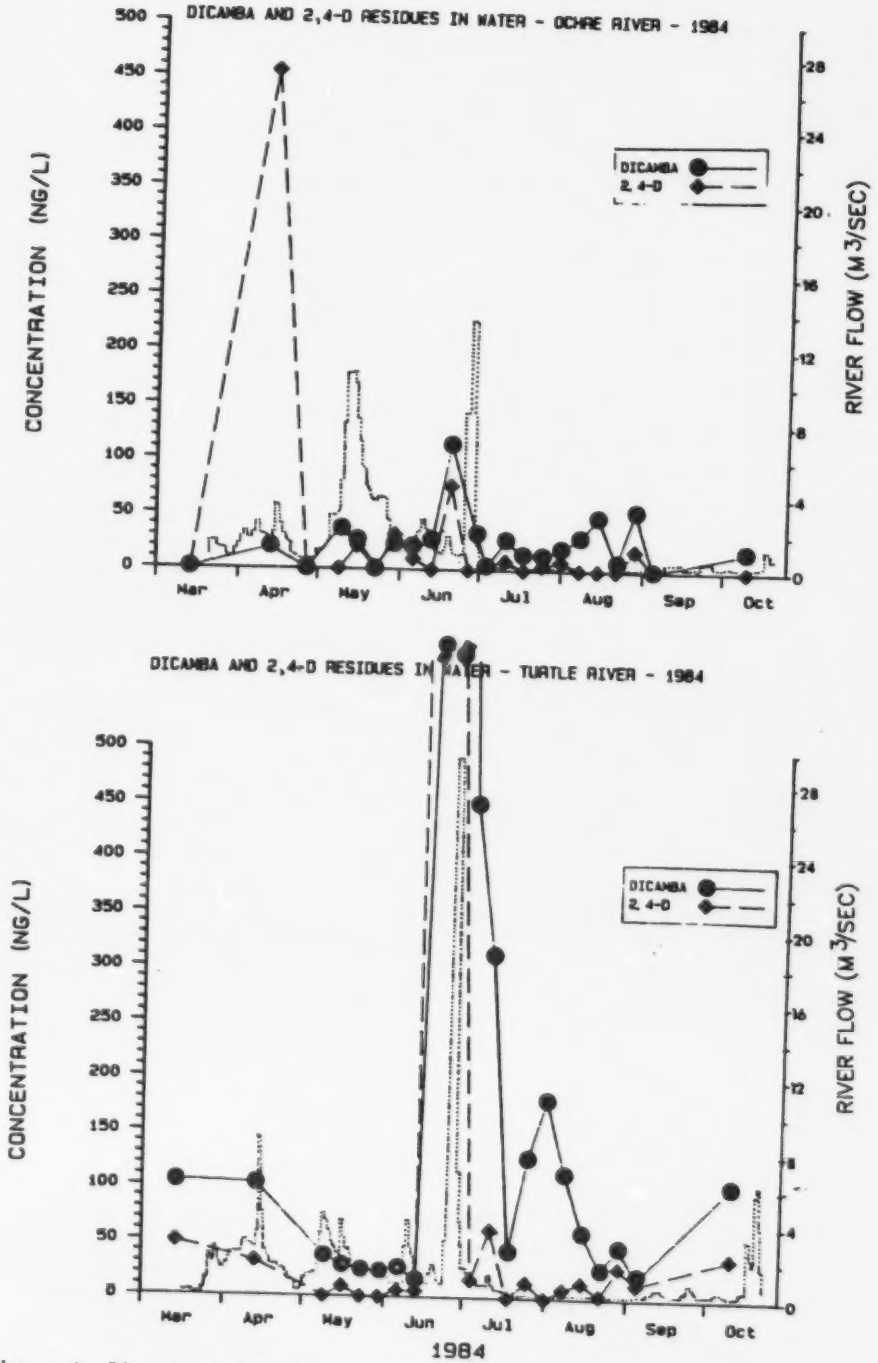


Figure 3. Dicamba and 2,4-D concentrations (ng/L) and river flow (m^3/sec) in the Ochre and Turtle Rivers during 1984.

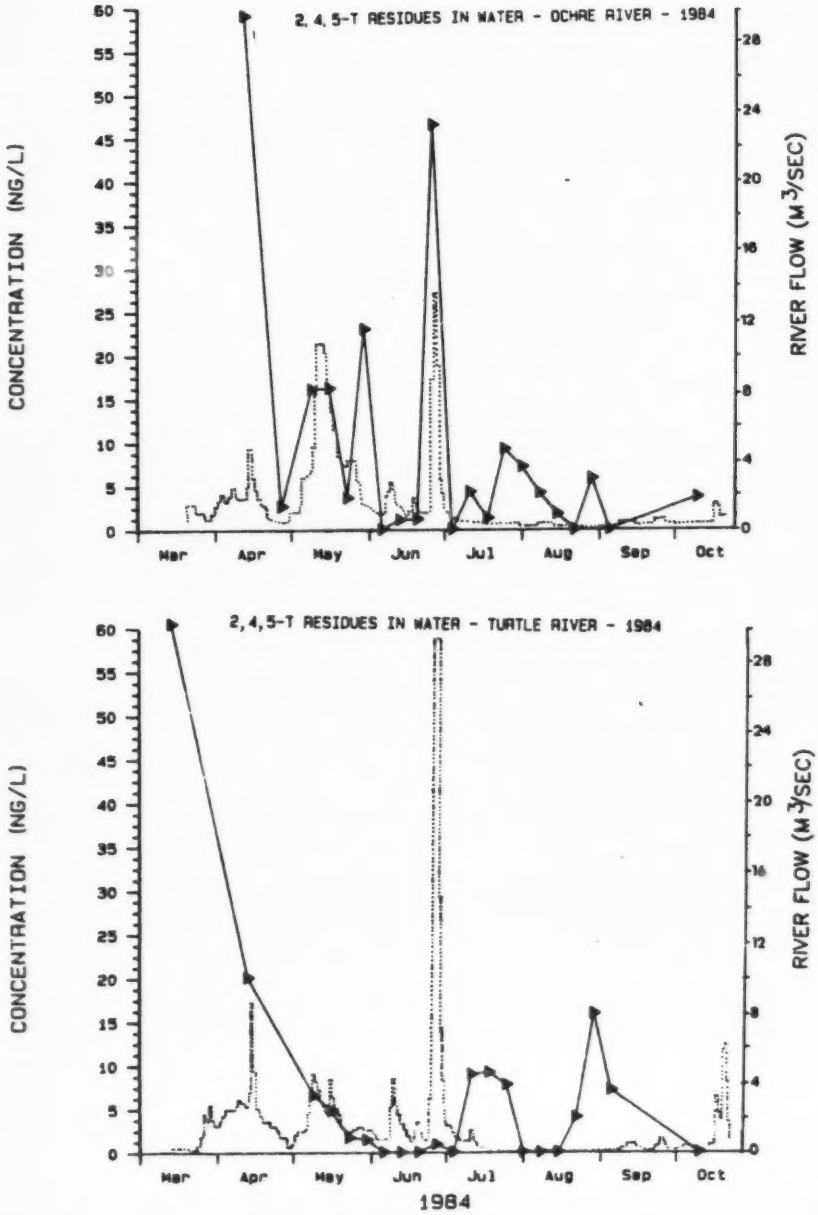


Figure 4. Residues of 2,4,5-T (ng/L) in the Ochre and Turtle rivers during 1984.

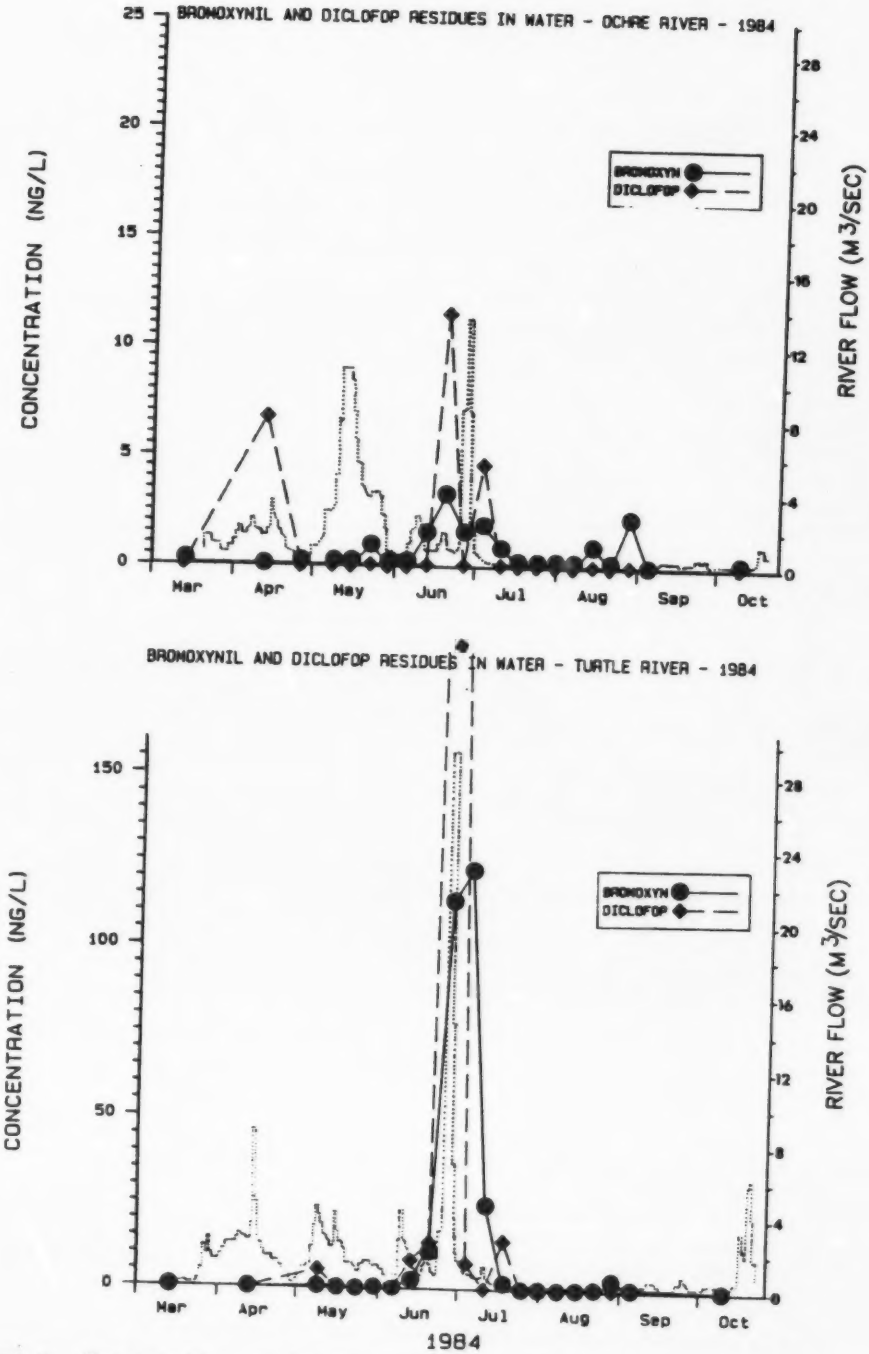


Figure 5 . Bromoxynil and diclofop concentrations (ng/L) and river flow (m^3/sec) in the Ochre and Turtle rivers during 1984.

MEASUREMENT OF SOIL EROSION BY RAINFALL

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In an attempt to develop a rainfall erosion prediction equation for use as a soil conservation tool, American researchers analysed over 10,000 plot years of data from about 50 locations in 24 states east of the Rockies. This work produced a six factor empirical equation commonly known as the Universal Soil Loss Equation (USLE). Testing of the equation in many parts of the world has led to its acceptance and usage with only minor, if any, modifications. Many workers in Western Canada have felt that the close proximity of the region to the area in which the equation was developed warrants its indiscriminant use in conservation practice recommendations and research. However, Prairie agronomic and meteorological factors that led to higher organic matter contents, different clay mineralogy, a more humid, cooler climate, and different crop-management systems, in these regions compared to the locations where the American research was done, cause one to question the validity of the equation's relationships under Western Canadian conditions. To the writers' knowledge, no measurements of soil loss by rainfall have been made in Manitoba. The current research was undertaken in order to evaluate the USLE under Manitoba conditions.

The Universal Soil Loss Equation

The universal soil loss equation is:

$$A = R K L S C P$$

where: A = computed soil loss per unit area (Tonnes/Ha)

R = rainfall factor. The number of erosion index units in a particular storm or year. The erosion index is a measure of the erosive force of specific rainfall.

K = soil erodibility factor. Erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow on a 9% slope 22.13 metres long.

L = slope-length factor. Ratio of soil loss from the field slope length to that from a 22.13 metre length on the same soil type and the same gradient.

S = slope-gradient factor. Ratio of soil loss from the field gradient to that from a 9% slope. (Usually the factors L and S are combined into one term.)

C = crop management factor. Ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which the K factor was evaluated.

P = erosion control practice factor. Ratio of soil loss with contouring, strip cropping or terracing to that with straight row farming, up and down slope.

MATERIALS AND METHODS

Field Research Two sites of different soil texture were chosen for the research. The first site, on a Gretna clay near Miami was established in the summer of 1984. The second, on a Leary sandy loam, was established in the spring of 1985.

Plot dimensions were 22.13 x 4.6 m (72.6 x 15 feet) on a uniform 9% slope, so chosen because they matched the dimensions of the standard erosion plots used most frequently in the development of the USLE. The topographical factors of the equation (LS) are numerically equal to 1.0 under these standard plot conditions, and thus are eliminated when analysing other factors in the equation. Spruce boards, 2.5 x 20 cm (1 x 8 inches) inserted 8 cm into the soil along the plot periphery made an effective barrier to water movement onto or off the plot. Removable end boards allowed for access onto the plots by machinery.

Coshocton samplers were chosen as the means of sampling the runoff and sediment (figure 1). A 61 x 76 cm (24 x 30 inch) patio block was used as a base to support a stand which in turn supported the sampler and water level recorder. The sampler consisted of a 15 cm (6 inch) high flume which directed a stream of runoff water onto a finned wheel causing the wheel to rotate. The 30 cm (12 inch) diameter wheel had on its surface an elevated slot along the radius of the wheel. As the wheel was propelled, the slot passed under the flow once per revolution. At this time, runoff flowed into the slot and collected in a holding pan under the wheel. Since the area of the slot was 1% of the wheel, the sampler collected 1% of the runoff and sediment. It then flowed by gravity through piping into removable collection containers. These containers consisted of 20 1 pails that were connected in series and filled differentially.

Attached to the side of the flume was a stilling well in which the float from the water level recorder was housed. Runoff water entered this well through holes in the side of the flume. Float, and therefore water level height, were recorded on the water level recorder. Using the relationship between water level and flow rate obtained during calibration, the runoff rate during each storm was calculated.

The sampler, stand, water level recorder and pails were housed in a large plywood box, the top of which doubled as a swing-back lid for easy access.

A 4.6 m (15 foot) long trough was installed at the base of each plot to collect the runoff and direct it into the flume. The trough was 28 cm (11 inches) wide and was sloped at 10% from one end to the other. The lower end of the trough was bolted to the flume and sealed at this

joint with silicone. The trough was dug into the ground such that the edge against the plot was 5 cm (2 inches) below the soil surface. This allowed for unrestricted flow into the trough. The back of the trough was 30 cm (12 inches) above the soil surface to provide support for the attachment of a plywood lid. Angle iron was suspended 15 cm (6 inches) above the trough's front edge to provide support for the lids. Excavation for the troughs and samplers as well as drainage pipes leading away from the runoff collection system in each plot was accomplished by a back hoe.

After each runoff event, the collection pails were exchanged with empty ones and soil that settled out in the troughs collected. These samples were then oven-dried and weighed to determine the amount of soil lost from a plot during the given rainstorm.

Tipping bucket and standard rainguages were installed at each site a short distance from the plots. Rainfall data was used to determine the rainfall erosivity factor, R. Rainfall from a weather station located approximately equidistant between the two sites was used in instances where there was a large discrepancy between data from the standard and tipping bucket rainguages on site.

Four different crop-management systems - 1) continuous alfalfa, 2) continuous wheat (residue removed, stubble cultivated), 3) continuous corn (residue removed, stubble cultivated), and 4)continuous summerfallow - were represented by one plot each on each site. The Gretna clay was seeded in 1984 and 1985, the Leary sandy loam in 1985 only. Varieties used were Rambler alfalfa, Benito wheat and Pioneer 3995 corn. Seeding and fertilizing were done according to guidelines outlined in Field Crop Recommendations for Manitoba. For weed control, Embutox E, Hoe-grass II and Aatrex Plus were used on the alfalfa, wheat and corn plots, respectively.

Alfalfa was underseeded to wheat seeded at one-half rate in the establishment year. 1985 became the establishment year for both sites as the catch on the Gretna clay in 1984 was too poor to maintain a stand. The alfalfa seed was broadcast on the prepared seedbed and harrowed over twice. All wheat was drill seeded and corn was hand planted. Row spacings for wheat and corn were 18 cm (7 inches) and 91 cm (36 inches), respectively. Wheat and corn plots were cultivated once before seeding and once after harvest. Corn plots were also row culitvated twice during the growing season. Summerfallow plots were cultivated every three to five weeks. All of the tillage operations were done up and down the slope in order to remove the conservation practice factor (P) from the analysis, i.e P = 1.

Harvesting of all wheat took place at crop maturity. Corn was harvested at about 65% whole plant moisture. Stubble height ranged from 10-20 cm for wheat and 5-10 cm for corn. All plant residues were removed. Plant dry matter and seed yield were determined.

Degree of ground cover determinations were made throughout the growing season using the point-line method. A 150 cm (5 feet) rope with ten evenly spaced markings was used when crops were short. A horizontal bar supported by 2 vertical stands was used at later growth stages.

Lab Research Ten soil samples were taken in a grid pattern across the plots at each site. These were analysed for particle size distribution and organic matter content. Structure and permeability will be estimated from Soil Survey reports. These data will be used to determine the soil erodibility factor (K) from the USLE nomograph. In addition, K will also be calculated from an equation proposed by Young and Mutchler (1977). This equation uses data from particle size analysis, bulk density, aggregate index, dispersion ratio, and % montmorillonite in the soil.

Analyses Under the management practices described for summerfallow, the crop management factor (C) was equal to one. For the other plots, C varied throughout the year with crop stage.

The C factor for each crop-management system will be determined comparitively for different crop periods using the formula:

$$C = \frac{A \text{ (loss from cropped plot)}}{A \text{ (loss from fallow)}}$$

These will be compared to those given by Wischmeier and Smith (1978).

The K factor for each soil will be determined in three ways. Since LS and P have been eleminated:

$$A = R\,K\,C$$

C for summerfallow is equal to 1.0. By re-arranging the equation we have:

$$K = \frac{A \text{ (Soil loss from fallow)}}{R \text{ (erosivity of rainfall)}}$$

This experimentally determined value will be compared to that calculated using the USLE nomograph and the Young and Mutchler equation.

RESULTS AND DISCUSSION

The collection system for the Gretna clay site became operational in August, 1984. One erosive rainfall event occurred in October, after harvesting and cultivation had been completed. Losses were contrary to expectations - loss from wheat > loss from summerfallow > loss from alfalfa > loss from corn - and point out the need for many replications

of events under many different cropping periods in order to gain an average prespective on the values. The results may also show evidence of the soil returning to equilibrium after being disturbed by equipment installation. Visual inspection of the Gretna clay revealed a high shrink-swell characteristic, allowing for high infiltration rates in dry periods, changing to very low infiltration in the tightly packed wet soil.

The Gretna clay and Leary sandy loam sites became operational on May 9 and June 4, 1985, respectively. Both sites were dismantled on October 25, 1985. During this period, the Gretna clay site received ten rainfalls greater than 12.5 mm, and three greater than 25.0 mm. The Leary sandy loam site received six rainfalls greater than 12.5 mm, and two greater than 25.0 mm. Two heavy August rainstorms of about 60 and 125 mm were included in these. The Gretna clay has 13 runoff events while the Leary sandy loam had ten.

Ground cover and final yields were low for all plots except the Leary sandy loam alfalfa which reached expected levels of cover (Table 1). Cover and yields were greater on the Leary sandy loam plots for all crops. Herbicide damage on the Gretna clay wheat led to its eventual reseeding in mid-July and subsequent poor stand the remainder of the year.

Table 1. Crop characteristics for both sites in 1985.

Site	Plot	Seeding Date	Maximum ground cover		Harvest Date	Yield	
			During Growing Season(%)	After harvest (%)		PDM (t/ha)	grain (t/ha)
Gretna clay	alfalfa(w)	June 10	61	51	Oct 2	1.76	1.14
	alfalfa(a)	June 10	61	51	Oct 2	0.01	-
	wheat	Apr 29	60	5	-	-	-
	corn	May 23	38	4	Sept 25	4.02	-
Leary sandy loam	alfalfa(w)	May 22	85	84	Sept 10	1.72	1.03
	alfalfa(a)	May 23	85	84	Sept 10	1.08	-
	wheat	May 22	62	44	Sept 10	2.47	1.51
	corn	May 23	44	3	Sept 25	4.33	-

The total rainfall and erosivity (R) values have been calculated for some of the major storms at the Gretna clay site (Table 2). Due to inadequate collection capacity, the soil loss values for August 17 reflect only that which could be collected. Soil loss was probably greater than that which was recorded.

The very low soil losses for the August 4 storm may be partially due to the fact that the storm had three peaks of high intensity rainfall

followed by a valley of low intensity after each peak. Sedimentation may have taken place on the wheel as the runoff velocity decreased after the first peak causing the rotation of the wheel to cease and no sampling to take place during the remainder of the storm. Large build-ups of soil on the wheels after the storm lent credence to this hypothesis.

Table 2. Rainfall characteristics and soil losses associated with major storms at the Gretna clay site.

Date year, month, day	Total Rainfall (mm)	Maximum 30 min Intensity (mm/h)	Rainfall Erosivity Factor R ($MJ\ mm\ ha^{-1}\ h^{-1}$)	Soil loss (T/ha) from alfalfa	wheat	corn	fallow
84 10 15	42.6	9.6	738.0	0.01	0.13	-	0.07
85 5 12	38.4	26.4	188.4	-	0.57	0.56	0.56
85 5 29	17.6	9.2	30.9	-	0.13	0.63	0.25
85 6 28	19.4	4.0	11.9	-	0.51	1.38	-
85 8 4	59.8	48.0	706.5	0.18	0.34	0.35	0.15
85 8 17	129.8	30.0	817.1	3.82	18.99	10.34	28.82
85 9 20	12.8	3.6	3.2	0.01	0.05	0.01	0.08

The actual soil from the various storms followed no distinct pattern. The expected order of soil loss would be: fallow>corn>wheat>alfalfa. Only the last two rainstorms seemed to follow this order, the poor wheat stand at the time accounting for the very high values on that plot.

The annual R value for Southern Manitoba is about 1000 MJ mm ha^{-1} h^{-1}. Storms on August fourth and 17th each had R values of this magnitude. This suggests that rainstorms with very high erosion potential can occur from time to time. A storm like this, occurring during a crop stage offering low ground protection, could be devastating. Also, if these storms represent a yearly average of R, it would follow that they represent an average annual soil loss as well. Soil lossed from at least two of the plots surpassed the tolerable soil loss limit of 11 t/ha.

REFERENCES

Field Crop Recommendations for Manitoba. 1984. 1985. Manitoba Department of Agriculture.

Wischmeier, W.H., and Smith, D.D. 1978. Predicting rainfall erosion-a guide to conservation planning. U.S. department of Agriculture, Agriculture Handbook No. 537.

Young, R.A., and Mutchler, C.K. 1977. Erodibility of some Minnesota soils. J. Soil and Water Conserv. 32: 180-182.

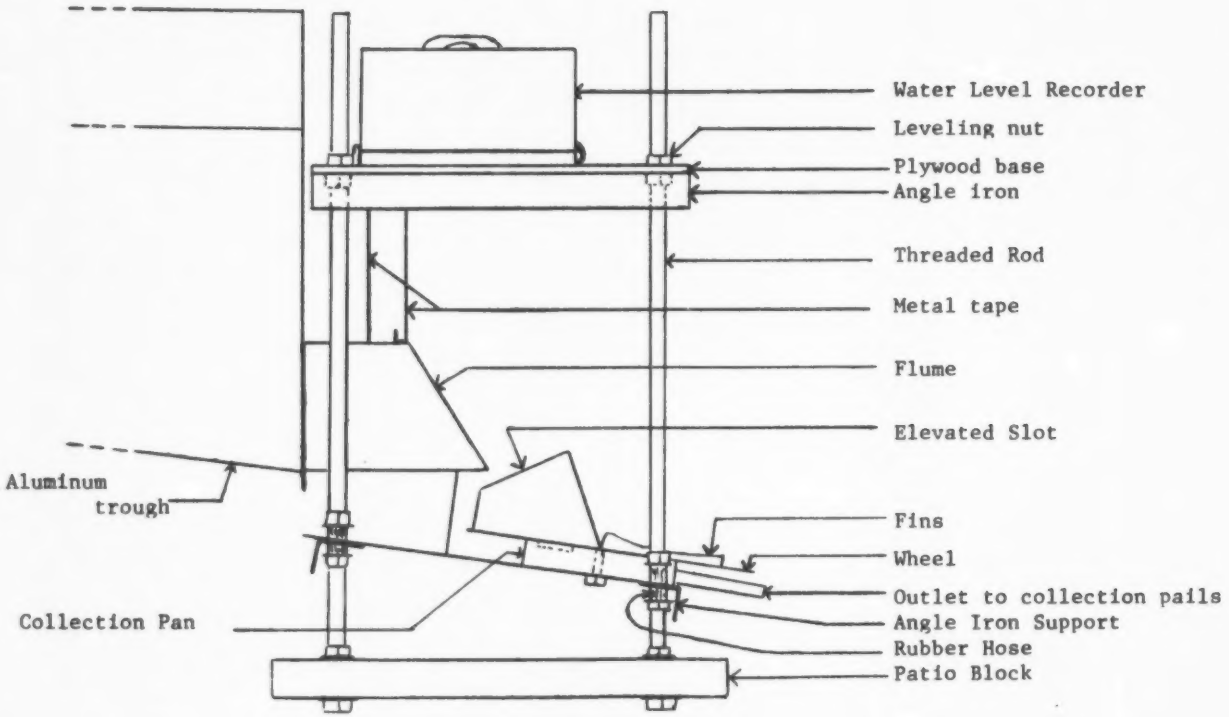

Figure 1. Side view of Coshocton sampler, water level recorder, and trough.

SOIL CONSERVATION AND PFRA

by
Floyd Wilson
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PAST

PFRA's activity in soil conservation goes back to the Prairie Farm Rehabilitation Act, 1935, which authorized the Minister to undertake works to...secure the rehabilitation of the drought and soil drifting areas...in the prairie provinces. Following World War II, PFRA's involvement waned but rekindled in the early 1980's chiefly because of farmers demands for assistance. Pilot projects were established at several locations - Warner, Alberta, Swift Current and Weyburn in Saskatchewan, and Turtle Mountain in Manitoba all dealing with salinity, at Crystal Lake, Saskatchewan, on wind erosion, and in the Rural Municipality of Thompson in Manitoba dealing with water erosion. There were other responses - PFRA issued, following extensive literature review and discussion with farmers, research, and extension personnel, their report on Land Degradation and Soil Conservation Issues which put forth PFRA's perspective of the problem. The Senate Standing Committee report - Soils at Risk - received much national exposure, and more locally the Soil and Water Resources Task Group report brought forward some 17 issues. Amongst these were:

X erosion by wind and water
XI organic matter and fertility loss
XIV land evaluation
XV soil salinity.

I do not believe that the 17 issues were ranked in perceived importance, for if they were, the only consolation we may draw is that these were listed ahead of soil fertility and Soil Survey. There were, of course, many others individually and as contribution to other works, raising soil conservation awareness.

After several years of discussions, the Economic and Regional Development Agreement (ERDA) agreements were signed in November, 1983, and the consequent Canada/Manitoba Subsidiary Agreement on Agri-Food Development in May, 1984. These Agreements had, amongst other objectives, an objective to facilitate the development, design, and on-farm adoption of improved soil and water management practices to assist the long run viability of the farm sector. More specifically, the Enhanced Soil and Water Program of the Agri-Food Agreement Sub-Program 3 on Soil Conservation and Management supports:

- the delineation and control of soil problems
- demonstration of soil degradation reduction and rehabilitation techniques
- demonstration of soil moisture management measures to mitigate moisture deficiencies
- efforts to improve the efficiency of fertilizer use and chemical control.

PFRA has applied for and received authority to overesee spending of $4M of the $4.5M federal funds committed to this Sub-Program in Manitoba. In Saskatchewan, we are spending $8M and Alberta $3M on soil conservation activities.

PRESENT

In Manitoba, with these funds, we propose to:

1. reduce the extent of soil degradation problems experienced by individual producers through the provision of an on-farm soil conservation service;

2. identify the nature, location, and severity of soil degradation problems and to establish benchmark sites for monitoring ongoing degradation and measuring the effectiveness of conservation practices;

3. increase the awareness of soil conservation among the farming community and the public at large.

To digress for a moment to things that we have done. We have hired three area conservationists and three technicians, who are stationed in our area offices in Morden, Brandon, and Dauphin, and a senior conservationist stationed in Winnipeg. We have developed, with the province, guidelines for cost-sharing various conservation practices, and with the Province and conservation groups, jointly developed action plans in 13 areas to deal with conservation issues. There is in place, a Soil Conservation Liaison Committee, its composition currently under revision, to keep all the actors involved and informed, and we are in support of the Provincial Strategy for Agricultural Soil and Water Management in Manitoba.

To return to what we propose to do, that is - an on-farm soil conservation service, degradation monitoring, and awareness - I would like to deal with them in reverse order recognizing that they are not separate issues.

3. **Awarness**

Awareness is in part a prairie wide approach to:

- assist in development of a wide range of extension materials for distribution
- assist in promoting a "conservation ethic" or "stewardship of the land"
- assist in efforts to transfer research results to producers.

We have produced various promotional and informational items using the slogan "Soil Conservation - farming for tomorrow - today," organized a tour of soil specialists, conservation farmers, industry to observe North Dakota and Montana conservation programs at the farm level, had conservation displays at field offices and agricultural shows, had floats in parades, made presentations to

municipal gatherings, high schools, and other groups. These kinds of activities will continue.

We are preparing this winter, a conservation van to tour summer fair circuits, will soon be founding some 4-H soil conservation related projects, supplying conservation material to elementary and high schools, and offering a financial incentive in soil conservation awareness to post-secondary institutions.

2. **Regional Degradation and Monitoring**

Some progress has been made in identifying the nature, location, and severity of degradation problems. The Canada/Manitoba Soil Survey has produced or is in the final stages of completion 1:1 Million scale maps showing degradation. We would also support a second generation of this information at a scale of 1:100,000 or so. We would prefer in these issues of degradation and monitoring to offer a supportive rather than take a lead role. The lead could be assumed by those in possession of data, or in a position to obtain the data, such as the Canada/Manitoba Soil Survey, the University of Manitoba, perhaps the Remote Sensing Centre or others, and we would like to contribute to and support these as joint efforts.

1. **On-Farm Conservation Service**

Our conservationists are available as time and material permit, to work with any farmer on soil conservation. We have, however, restricted financial incentives to members of organized conservation groups. We have agreements with and committed funding to 13 conservation groups throughout the province; these are located at Washow-Icelandic area, South Interlake, Seven Sisters, Stuartburn-Piney, Winkler, Dufferin, Pembina, Deerwood, St. Alsphonse-Bruxelles, Delta, Elgin Plans, Turtle River, and Cowan and we soon expect to have agreements with Whitemud, The Pas, Minitonas, and perhaps Virden-Elkhorn. All of these agreements have been cooperative efforts between the Province, the conservation organizations, and PFRA, with shared funding, our share ranging from $57,000. to $249,000. The conservation practices that are cost-shared are saline seep recharge area treatments, critical area treatment, shelterbelt establishment, maintenance and renovation, annual barriers, wind stripcropping, contour stripcropping, erosion control structures, grassed waterways, conservation tillage systems, green manure, annual cover crops, vegetative cover, special equipment, administration, and awareness. The cost-sharing varies from 50% for green manure and some other treatments, to 100% for shelterbelt establishment and maintenance. Of the $1.4M committed so far:

7.5% is toward salinity
17.3% is toward wind erosion
16.6% is toward water erosion
25.0% is toward conservation tillage
16.9% is toward other soil and water management practices
3.7% is toward conservation organization administration
1.6% is toward conservation organization awareness activites

9.9% is toward specialized equipment
1.0% is toward "other activities"

The payment to the cooperating farmer on these selected practices is through the conservation organization.

This cost-sharing, adapted to the needs of the areas through consultation between the farmers of the conservation organizations, the Province, and PFRA, the activities of the conservationists, and the delineation of the nature and extent of degradation problems, are small steps along the soil conservation road in Manitoba.

FUTURE

We expect to have funding for the life of the ERDA Agreement and well beyond that, subject to all the politics of the situation, to carry out the kinds of activities here described at the farm level in cooperation with the Province, farmers, researchers, and others and in such a way that we may, at any time in the future, look back and say that soil conservation in Manitoba is better off for our having been there.

MANITOBA CONSERVATION DISTRICT SOILS PROGRAMS

W. R. Poole, Manager

Turtle Mountain Conservation District

Abstract:

Prior to 1972, the Province of Manitoba - through its agriculture department - participated directly in cost-sharing some soil conservation practices with farmers. Gully stabilization projects were the most common type of work under that program.

More recently, provincial financial support for the installation of soil conservation measures on farms has occurred indirectly, with funds being made available for cost-shared programs within Manitoba's five conservation districts. Since they operate under legislation administered by the Department of Natural Resources, the funds are channelled through that department.

The nature and extent of the soil conservation programs currently offered by the districts are outlined, as are some of the soil management demonstration projects being conducted with other sources of funding.

Introduction:

At the present time, there are five conservation districts operating in Manitoba, covering about 15 percent of the agricultural land in the province. Topography and soil type vary widely; both within and between districts. Fortunately, because of the structure of the Conservation Districts Act, there is enough flexibility that each district's programs can be based on local priorities and can even be targeted to specific areas within each district.

Perhaps before considering specific programs, I should take a moment or two to briefly outline how conservation districts are established, financed and administered. To date, districts have been formed as a result of one or more municipalities becoming concerned about resource management problems and requesting the province to form a district.

Since the districts are also responsible for water management programs, most are formed on a watershed basis although they may also follow municipal boundaries. They are further divided into sub-districts on the basis of sub-watersheds.

Each municipality having land within a sub-district appoints two people - one council member and one ratepayer - to a sub-district committee. They are responsible for recommending an annual works program for their area to a central board composed of all the sub-district chairmen plus a representative of the province.

The central board priorizes the requests for work from the sub-districts and also develops those programs which are available on a district-wide basis. They are responsible for

finalizing the district budget.

Funds for conservation district programs come from both provincial and local sources. In the budgets of all the districts, provincial funds make up about 75 percent of the total. The other 25 percent is raised locally through municipal assessment, direct charges to benefitting landowners and grants from non-government sources. Ducks Unlimited (Canada) has been a prominent source of non-government funds in some districts.

Soils Programs:

Because of the extremely close relationship between soil and water management, it is somewhat difficult to split conservation district programs into one class or the other. There are, however, some programs which are usually thought of as being primarily soils-related and I'll consider them first. All are cost-shared 75 percent province : 25 percent landowner.

a) Forage Seed Assistance - With the exception of Cooks Creek, each of the districts offers a forage seed assistance program. Under it, landowners can apply for a specified acreage of forage seed for qualifying land.

In the three northern districts - Whitemud, Turtle River and Alonsa - the program is limited to Class IV or lower land. Our district uses different standards, making the program available on land subject to erosion or salinity.

From 1980 to the present, the districts have purchased 654,665 kgs. of forage seed - worth $1,340,945 - for seeding on 57,931 hectares. That amount of forage land, which must remain seeded down for a minimum time period ranging from three to five years, has a significant impact in local areas.

Rates of erosion and runoff are reduced substantially while the forages remain in production and often for several years after the land is returned to annual crop production. In addition, I would think that the program has a significant effect on the market for forage seed grown in Manitoba.

b) Field Shelterbelts - In the Whitemud district in particular, field shelterbelt plantings have been a very significant program. From 1975 to the present time, that district has operated the largest organized planting program in North America.

In that eleven year span, they have planted 1450 kms. of trees, most of them in single row field belts on the lighter soils in their district.

Our district has also done some planting although not nearly at the Whitemud's scale. We put in 99 kms. from 1979-1983 - all single row green ash field belts. In addition to planting programs, some districts have also done renovation work - particularly thinning - on established shelterbelts to improve snow distribution.

c) Gully Stabilization - The kind of work which used to be done by the department of agriculture to reslope and seed down eroded gullies in agricultural land has been continued by the conservation districts. Although not a major part of the districts' soils program, gully stabilization projects significantly

reduce erosion and downstream sedimentation where they do occur.

d) Demonstration Projects - Often in co-operation with other agencies, several of the districts have undertaken demonstration projects in relatively new soil and water management techniques.

The Whitemud, for example, has done a considerable amount of work on the aerial seeding of fall rye on potato ground in the Carberry area to try and reduce the risk of wind erosion.

Several years ago, Ducks Unlimited purchased a Haybuster undercutter cultivator and placed it in our district for two years to demonstrate stubble mulch tiliage on summerfallow. The machine was subsequently moved to Saskatchewan and then to Alberta to continue those demonstrations.

Turtle Mountain has also done a demonstration project on pothole concolidation in cropland in co-operation with Manitoba Agriculture. The testing of small scale irrigation methods was also included in that demonstration.

In 1986, the Turtle River Conservation District will be starting a major five-year soil management project funded under the federal-provincial ERDA program. The federal government will contribute $127,000 and Manitoba Agriculture $40,000 toward the cost of the project.

Reduced tillage, cover crop plantings and perennial shelterbelts will be used to control wind erosion and improve soil organic matter levels. In addition, the economics of on-farm soil conservation practices will be evaluated.

Conclusion:

Substantial provincial involvement plus the strong local autonomy granted them place Manitoba's conservation districts in a unique position in resource management in North America. No other agency on this continent is better structured to provide local administrative support to soil and water conservation programs.

With the continued support of professionals like yourselves, our conservation districts will be able to play an ever-expanding role in the transfer of new management technologies to this province's farm population.

Table 1 - Assisted Forage Seeding (ha.)

Cons. District	1980	1981	1982	1983	1984	1985	Total
Whitemud	5,312	6,028	3,401	3,211	3,365	3,662	24,979
Alonsa	1,932	2,103	2,252	2,086	2,420	2,676	13,469
Turtle River	1,967	1,743	2,326	2,324	994	1,038	10,392
Turtle Mountain	1,335	1,712	1,754	1,093	1,497	1,700	9,091
							57,931

Table 2 - C.D. Forage Seed Purchases

	Kg. Purchased	Value
1980	113,842	$233,419.
1981	124,101	256,341.
1982	108,304	175,618.
1983	104,112	252,829.
1984	94,614	203,203.
1985	109,692	219,535.
Totals	654,665	$1,340,945.

Table 3 - Field Shelterbelt Plantings (km)

Cons. District	1980	1981	1982	1983	1984	1985	Total
Whitemud *	114	119	105	92	85	129	644
Turtle Mountain **	32	31	7	3	-	-	73
							717

* Also planted 805 kms. from 1975'79 (inc.)

** Planted 26 kms. in 1979